ARMY RESEARCH LABORATORY

Human Factors Evaluation of Land Warrior, Version 1.0

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Samson V. Ortega, Jr., and Rhoda M. Wilson

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Human Research and Engineering Directorate, ARL

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14. ABSTRACT
The Human Research and Engineering Directorate of the U.S. Army Research Laboratory conducted a human factors evaluation (HFE) of the Land Warrior system as part of the Land Warrior Safety Test conducted by Aberdeen Test Center at Aberdeen Proving Ground, Maryland, in March 2002. The primary objective was to identify human factors issues associated with the Land Warrior system. Five assessments were conducted as part of the HFE: glove compatibility, shooting performance, weapons compatibility, mobility and portability, and range of motion. Several issues were identified, and recommendations to alleviate the potential problems and increase overall system effectiveness are discussed.

15. SUBJECT TERMS
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Executive Summary

The Human Research and Engineering Directorate of the U.S. Army Research Laboratory (ARL) conducted a human factors evaluation (HFE) of the Land Warrior (LW) System as part of the Land Warrior Safety Test conducted by Aberdeen Test Center in March 2002. The primary objective was to identify human factors issues associated with the LW system. Five assessments were conducted as part of the HFE: glove compatibility, shooting performance, weapons compatibility, mobility and portability, and range of motion. Participants were 12 infantry Soldiers from the 82nd Airborne Division, Fort Bragg, North Carolina. All Soldiers were 11 series infantry military occupational specialty. Before the assessments, all participants were trained to wear and operate the various components of the LW system.

ARL examined the compatibility of the LW soldier control unit (SCU) input device with various gloves worn by Soldiers and identified any input device design characteristics that may impact user performance. Seven Soldiers participated in the assessment. Participants donned the LW system (without the M45 mask) and performed an alphanumeric text entry task with the LW input device during five conditions: (1) bare handed, (2) bare handed in a dark room, (3) wearing a leather utility glove, (4) wearing a 25-mil nuclear, biological, and chemical (NBC) glove with liner, (5) wearing a trigger finger mitten with liner. Each text entry task was 60 characters long and consisted of random words and numbers. Participants used the input device and a soft keyboard presented on their helmet-mounted display (HMD) to perform the text entry task. Three of the seven participants also performed the text entry task with the LW system with the M45 mask during two conditions: (1) bare handed and (2) wearing the 25-mil NBC glove. After completing each text entry task, participants completed a questionnaire, giving their opinions about the physical effort required to use the LW SCU and the ease with which they could enter text and numbers. Dependent measures were task completion time (seconds) and questionnaire responses.

Results show that task completion time with the trigger finger mitten accounted for approximately 68% of the variance in task completion time. Performance was 44.4% slower than when the participants were bare handed and wearing the 25-mil glove, and 41.4% slower than when they wore the leather utility glove, which indicated that thick, bulky gloves may not be suitable for use with wearable input devices. Questionnaire data show that participants thought the SCU device was more difficult to use when they wore the trigger finger mitten because the thickness made it difficult for them to feel the control buttons on the input device and required them to use two hands to perform the text entry task. Task performance time was not affected by the chemical protective mask. However, participants noted that the HMD did not rest against the lens of the mask and they had to hold the HMD in place, making the text entry task a two-handed task.

Participant comments made during the course of the assessment indicated that there was a problem with dirt accumulating inside the input device, which made it difficult to position the cursor on the screen. They also mentioned that the backspace and clear buttons are situated next to each other on the soft keyboard, which made it easy to accidentally clear any entered text.

The findings of the glove compatibility assessment suggest that bulky gloves make input device usage problematic. Alternatives to the LW input device should be considered to ascertain if other designs may be more compatible with bulky gloves and may alleviate the problem of dirt accumulation in the device. Other design changes should be explored including modifying the HMD so that it rests against the lens of the mask and separating the clear and delete buttons on the soft keyboard to prevent information from inadvertently being deleted.

The shooting performance assessment determined the ability of participants to aim and fire the M4 carbine and M249 squad automatic weapon (SAW) weapon systems in day and night conditions with direct and indirect sighting methods, and the assessment identified any compatibility issues between the weapons systems and the LW system. There were five firing conditions: M4 daylight firing, M4 reduced exposure firing, M4 night firing, M249 daylight firing, and M249 night firing. The dependent measure was target hit percentage (targets hit divided by targets presented).

Twelve Soldiers participated in the M4 daylight firing assessment. Soldiers used the M4 with the M68 reflex sight (also known as close combat optic) and the daylight video sight (DVS) viewed on the HMD, to fire at targets at ranges of 50, 100, 150, 200, 250, and 300 meters, at target exposure times of 3, 5, and 8 seconds. Soldiers fired from the standing unsupported, kneeling unsupported, foxhole supported, and prone unsupported firing positions. Results of the M4 daylight firing show that shooting performance with the current M68 reflex sight (59% mean hit percentage) was better than shooting performance when the DVS was used (40% mean hit percentage), especially at the shortest target exposure time.

Eight Soldiers participated in the M4 reduced exposure firing assessment. Soldiers used the M4 with the DVS viewed on the HMD to fire at targets at ranges of 50, 100, 150, 200, 250, and 300 meters at targets exposure times of 8, 12, and 16 seconds. Soldiers fired the weapons from behind a wall in both the standing and kneeling firing positions. Results show that Soldiers were able to hit targets when viewing through their HMD, without exposing much of their body. The overall hit percentage for targets from 50 to 300 meters was 36%, but a considerable amount of time was needed to acquire and engage the target, and the targets had to be relatively close.

Eight Soldiers participated in the M4 night firing assessment. Soldiers used the M4 with the medium thermal weapon sight (MTWS) directly and the MTWS viewed on the HMD, to fire at targets at ranges of 50, 100, 150, 200, 250, and 300 meters, at target exposure times of 5 and 8 seconds. Soldiers fired from the standing unsupported and foxhole supported firing positions. Results show that Soldiers had much more difficulty firing with the thermal image presented on the HMD than when looking into the MTWS. The mean hit percentage was 36% with the

MTWS with inherent display and 12% with the MTWS displayed on the HMD. This may have been attributable to some problems with the "video out" on the MTWS.

Three Soldiers participated in the M249 daylight firing assessment. Soldiers used the M249 SAW with the M145 machine gun optic and the DVS viewed on the HMD, to fire at targets at ranges of 200, 300, 400, and 500 meters at target exposure times of 6, 8, and 10 seconds. Soldiers fired from the foxhole and prone firing positions. Results showed that Soldiers performed better when using the M145 machine gun optic (47% mean hit percentage) than when using the DVS viewed on the HMD (28% mean hit percentage), particularly at the shorter target exposure times. The direct view optic of the M145 may have provided a clearer picture, allowing for easier target acquisition.

Three Soldiers participated in the M249 night firing assessment. Soldiers used the M249 SAW with the MTWS (Omni version) viewed directly and on the HMD, to fire at targets at ranges of 200, 300, 400, and 500 meters at target exposure times of 6, 8, and 10 seconds. Soldiers fired from the foxhole and prone firing positions. Results show that Soldiers performed better when using the MTWS in the direct view mode (46% mean hit percentage) than when the image was viewed on the HMD (36% mean hit percentage).

Results of the shooting performance assessment suggest that Soldiers performed better when using the current direct view configurations than when firing with the HMD to acquire and aim at targets. Further research should be conducted to determine the factors that contribute to the degraded performance when Soldiers fire through the HMD.

The weapon compatibility assessment was conducted to determine how the LW system (including the ballistic armor load carriage system [BALCS]) and assault pack affect the Soldier's ability to hold, aim, control, and operate the M4 carbine (with and without the M203) and the M249 SAW. Six Soldiers participated in this assessment. Two Soldiers were configured as riflemen (with M4 carbine), two Soldiers as grenadiers (with M4 carbine and M203), and two Soldiers as M249 gunners (with M249 SAW). Four different LW clothing conditions were evaluated: LW with the fighting load carrier (FLC); LW with FLC and BALCS body armor (including detachable neck protector); LW with FLC, BALCS, and assault pack; and LW with FLC and assault pack. Participants assumed a standing, kneeling, and prone firing position using iron sights, M68 reflex sight, M145 machine gun optic, MTWS, or DVS, and determined if they could properly hold the weapon, aim the weapon, and operate the weapon and LW system. Participant comments were the dependent measure.

Most of the compatibility issues of the LW system and the weapon systems were attributable to the interference of the BALCS and assault pack with the helmet and the difficulty opening the MTWS eyecup. Often, in the prone firing position, the interference between the BALCS, assault pack, and the helmet prohibited the Soldier from sighting the weapon on the target. The eyecup on the MTWS was difficult to use in most firing positions and required Soldiers to push the

spectacles against the eyecup 3 or 4 times in order to get the full image. This problem was more pronounced in the prone firing position.

The buttstock positions of the weapons were also affected by the BALCS and the assault pack. As more straps and body armor cover the shoulder area, it becomes more difficult to find a place where the buttstock will seat properly.

Other problems noted by participants include the fact that the LW controls require the Soldiers to move their hands from their normal weapon firing positions. For the M249, the user interface device is on the pistol grip on the forestock. Most M249 gunners put their hand on the buttstock of the weapon. In this case, they must move their hand to the front of the weapon to access the controls. For the grenadier, the zoom wheel is situated in a position that is difficult to reach from a normal forestock hand position. These findings suggest that additional research and design work is necessary to solve this problem without eliminating adequate ballistic protection.

The objectives of the mobility assessment were to determine if there are any gross mobility issues with the LW system and to identify human factors and safety issues with the system. Twelve Soldiers participated in this assessment. Four Soldiers were configured as riflemen, four Soldiers as grenadiers, and four Soldiers as M249 SAW gunners. Three clothing conditions were evaluated: battle dress uniform (BDU), BDU with the LW System, and BDU with the LW System and BALCS with plate inserts. The Soldiers were instructed to complete the obstacle course as quickly as possible without compromising their safety. Soldiers were given a 30-minute rest break between obstacle course runs. Course completion time was the dependent measure.

The mean course completion time was 245.7 seconds for the BDU condition, 444.6 seconds for the BDU with the LW condition, and 559.8 seconds for the BDU with LW with BALCS condition. As the load increased from BDU to LW to LW with BALCS, so did the time to negotiate the course. In addition, the mean time to complete the course was shortest for the rifleman, slightly longer for the grenadier, and longest for the SAW gunner, because of the increased load that the grenadier and SAW gunner Soldiers are required to carry.

Three additional problems were identified during the assessment: the SCU and the cable between the body and the weapon were prone to snag on obstacles, and the bulkiness of the BALCS caused problems with mobility and slowed the Soldier.

Results of the mobility assessment suggest that modifications of the SCU and weapon cable would help prevent interference and breakage. Also, research into flexible and lighter body armor could greatly increase the mobility of the dismounted Soldier.

The objective of the range-of-motion assessment was to evaluate Soldier range of motion (ROM) when the Soldiers wore four equipment configurations: BDU, BDU with LW rifleman load-bearing equipment (LBE), BDU with LBE with BALCS, and BDU with LBE with joint service lightweight integrated suit technology (JSLIST). Twelve Soldiers participated in the assessment.

The dependent variables were total range of motion (in degrees) for head flexion, extension, rotation left, rotation right, lateral bending left and lateral bending right; shoulder flexion, extension, abduction and adduction; upper arm abduction; hip extension and flexion; and standing trunk flexion and extension.

Results indicate that of the 15 joint motions examined, 13 were significantly affected by equipment configuration. The BDU with LBE with JSLIST configuration appeared to place the most restrictions on Soldier ROM, with total ROM values for 13 of the joint motions being significantly lower than those of the BDU (baseline) configuration. Total ROM values for nine of the joint motions under the BDU with LBE with BALCS configuration were found to be less than those of the BDU (baseline) configuration, making it the next most restrictive. With only five total ROM values being significantly lower than those of the BDU (baseline) configuration, BDU with LBE was the least restrictive configuration.

For the BDU with LBE with JSLIST configuration, the total ROM values affected by equipment configuration were 18% to 37% less than corresponding values under the BDU (baseline) configuration. Head motions under the BDU with LBE with JSLIST configuration were primarily restricted by the hood of the JSLIST jacket. However, the canister of the mask was found to interfere as well, making contact with the subject's upper torso during head flexion. Reduction in total ROM for all the upper body motions, as well as hip flexion and extension, appeared to result from a lack of stretch in the garment's fabric. The bulkiness of the jacket fabric also contributed to the reduced total ROM for shoulder abduction and upper arm abduction, which forced the arm out and away from the body to a starting position value of approximately 25 degrees.

In comparison to total ROM values obtained under the BDU (baseline) configuration, values under the BDU with LBE with BALCS configuration were 17% to 47% less. Based on observation, reduction in total ROM values for the upper body motions can primarily be attributed to the bulkiness and lack of flexibility of the plates and vest that comprise the body armor. Shoulder abduction and upper arm abduction were also restricted by the shoulder straps of the LBE. Grenade and ammunition pouches on the front of the LBE also contributed to reduction in shoulder adduction total ROM. As with the BDU and LBE with JSLIST configuration, total ROM values for shoulder abduction and upper arm abduction were additionally reduced because of an increased starting position value (approximately 25 degrees), which resulted from the bulky body armor and the general purpose pouch on the side of the LBE, which forced the arm away from the body.

With respect to the total ROM values obtained under the BDU with LBE configuration, those found to be significantly affected by equipment configuration were 19% to 22% less than corresponding values obtained under the BDU (baseline) configuration. As with the BDU with LBE with BALCS configuration, shoulder abduction and upper arm abduction were observed to be restricted by the shoulder straps of the LBE, and shoulder adduction was observed to be

restricted by the grenade and ammunition pouches. Shoulder abduction and upper arm abduction total ROM were also reduced as a result of the general purpose pouch on the LBE that forced the arm out and away from the body, thus increasing the starting position value to around 21 degrees.

These findings suggest that additional work is needed to reduce the effect of equipment configuration on ROM. Increasing the size of the hood and enlarging the armholes of the JSLIST jacket may allow freer movement of the arms and head. Modifications of the shape, size, and position of the mask canister would allow for less restrictive movement of the head and neck. ROM restrictions associated with the BALCS may be alleviated by the use of several smaller plates instead of a few large plates, especially in the shoulder area. The inclusion of elastic in the shoulder straps of the LBE may mitigate restrictions of upper arm ROM, and alternate locations for grenade, ammunition, and general purpose pouches on the LBE may reduce interference with arm movements.

1. Background

The Land Warrior (LW) is the Army's "high tech" integrated Soldier-system designed to equip the dismounted Soldier for the future battlefield. The LW system will enable a Soldier to fight better at night and in all types of weather, communicate instantly with fellow squad members, and send real-time intelligence data such as photos and enemy position coordinates or concentrations of friendly forces (Garamone, 1998).

The idea of an integrated Soldier-system was first conceived in 1991 by an Army study group. In response, the Army initiated the Soldier integrated protective ensemble program (SIPE), whose goal was to integrate the Soldier with technology, thereby increasing lethality and survivability. Demonstrations of the SIPE program helped identify technologies that could be transitioned to the ensuing LW system (Spencer, 2000). The LW system consists of five subsystems:

1. The integrated helmet assembly (IHAS) features a helmet-mounted monocular display with flip-up design, thermal weapon sight (TWS), and video camera. The audio headset includes a chinstrap-mounted microphone and speakers mounted into the helmet suspension system.

2. A modular weapons system with the primary user weapons being the M16A4 rifle**,** M4 carbine, M240B machine gun, and M249 squad automatic weapon (SAW). Each weapon is fitted with a rail system to hold the following components: TWS, reflex or close combat optic (CCO), multi-function laser, video camera, and infrared aiming light.

3. Protective clothing and individual equipment, which consists of a soft armor ballistic protective vest with optional ballistic plates and load-carrying equipment. The modular packs consist of an approach pack, sustainment pack, and butt pack.

4. A wearable computer and radio, which features a global positioning system receiver, capture and transmission of video imagery, a squad radio with type 1 encryption, and a Soldier radio with type 3 encryption.

5. Computer software, which provides digitized map displays, overlays, signal operating instructions, and controlled messaging. The software allows images from the TWS and video camera to be transmitted to the IHAS and throughout the chain of command.

An LW-equipped Soldier is shown in figure 1. Several prototype LW systems underwent operational testing in 1996. Following the test, Soldiers commented that the system enhanced situational awareness, was user friendly and easy to learn, reduced Soldier workload, and improved squad communications. However, they recommended that the system be made lighter, have a more powerful battery, have better controls, and be made more rugged (Spencer, 2000).

Other technical and human factors issues that have been identified include equipment comfort, equipment compatibility, and inadequate load-carrying design (Government Accounting Office, 1999). Specifically, during field tests, Soldiers had problems raising their heads to fire their weapons from the prone position because the pack attached to the load-carrying harness rode up and pressed against the back of their helmets. Results of the operational test were used to modify the LW system in preparation for developmental testing, which began in 2001.

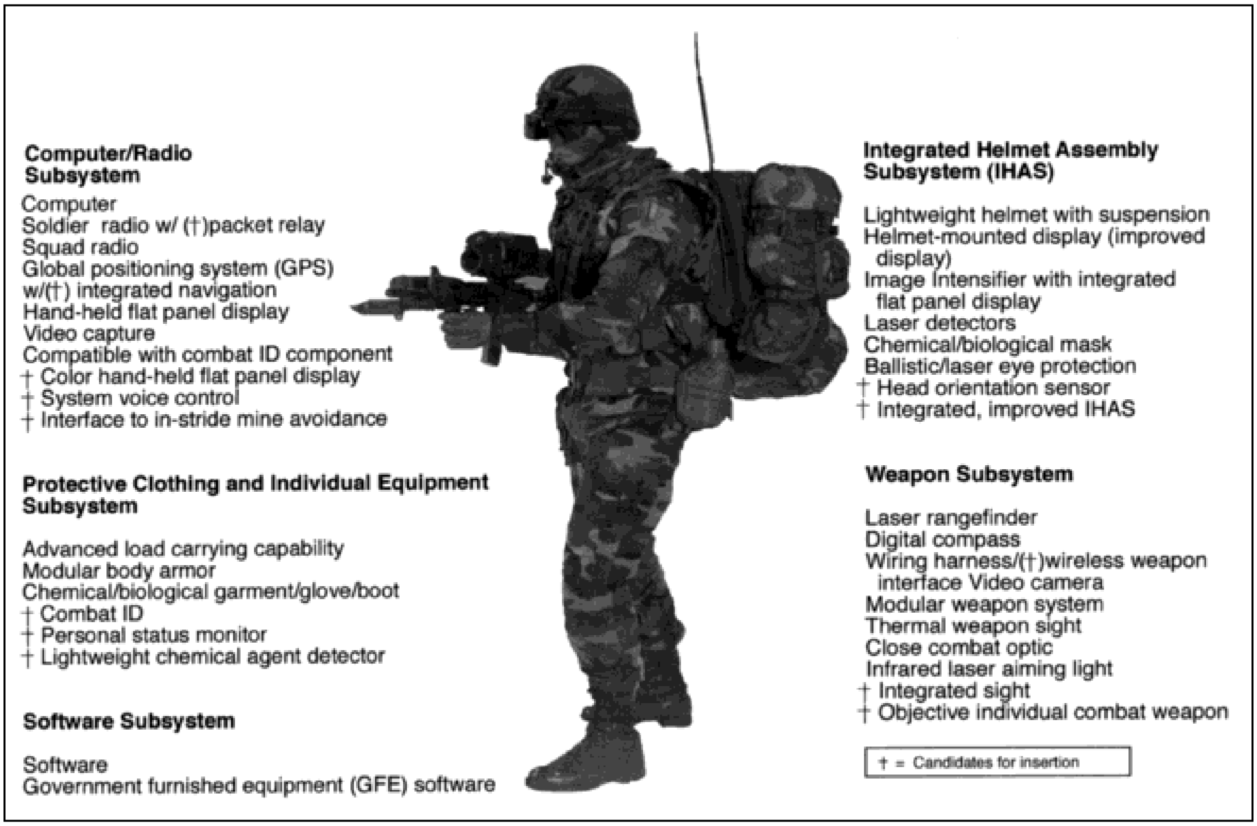

Figure 1. Land warrior system (version 1.0).

This report documents the findings of five human factors assessments, conducted at Aberdeen Proving Ground, Maryland, in May 2002, as part of the LW developmental test. During the test, the U.S. Army Research Laboratory's (ARL's) Human Research and Engineering Directorate assisted Aberdeen Test Center (ATC) personnel in performing the human factors evaluations in order to identify potential human factors issues associated with the LW system and to offer recommendations to improve overall system performance.

2. Objectives

The objectives of this evaluation were to

1. Determine the compatibility of the LW soldier control unit (SCU) with common Soldier-worn gloves.
2. Collect shooting performance data with Soldiers wearing the LW system while firing the M4 carbine, M249 SAW, and M240B machine gun in various firing conditions and with various sights (e.g., M68 reflex sight or CCO, daylight video sight (DVS), TWS).
3. Determine the compatibility of the LW Version 1.0 with various weapon configurations.
4. Identify any design characteristics or features that may impact mobility and portability from a human factors engineering (HFE) perspective and determine user acceptance for mobility and portability.
5. Identify components of the LW ensemble that impact Soldier range of motion (ROM).

In order to accomplish these objectives, five separate assessments were performed: glove compatibility, shooting performance, weapons compatibility, mobility and portability, and ROM.

3. Participants

Twelve Soldiers from the 82nd Airborne Division, Fort Bragg, North Carolina, participated in this evaluation. All Soldiers were 11 series military occupational specialty (MOS) infantry. Soldiers in this MOS series are normally required to carry pack loads, road march, and fire weapons as part of their duties. Participants' weapons qualification experience was a marksman rating or above for an M4 carbine or M16A2 rifle.

3.1 Orientation and Volunteer Agreement

The Soldiers were assembled and given an orientation about the purpose of the evaluation and their participation. They were briefed about the objectives and procedures for conducting the LW Version 1.0 safety trials. They also were told how the results would be used and the benefits that the military could expect from this investigation. In addition, the Volunteer Agreement Affidavit (DA Form 5303-R) (see appendix A) was explained and its contents were read aloud to the Soldiers. Next, the Soldiers were asked to complete and sign a volunteer agreement affidavit.

3.2 Medical Record Reviews and Medical Status Form

The Soldiers' medical records were not reviewed before this investigation. However, the investigators asked the Soldiers if any had a medical profile or history that would jeopardize their safe participation in this investigation, and all replied "no". The Soldiers also completed and signed a medical status form. A review of the medical status forms indicated that none had present injuries, none had recent surgery, and none were on profiles of any type.

3.3 Demographics and Anthropometry

Demographic and anthropometric measurement data were taken for each Soldier. These measurements were made in accordance with those described in the anthropometric measurement handbook (Clauser, Tebbetts, Bradtmiller, McConville, and Gordon, 1988). The measurements were converted to percentile values as shown in the 1988 Army Anthropometric Survey (Gordon et al., 1989). A summary of the anthropometric data is shown in table 1. The demographic and anthropometric data taken for each Soldier are shown in appendix B.

The dimensions of overall body size and proportions used to determine the anthropometric differences or similarities between populations are defined as the basic body descriptors, which are weight, stature, acromial height, and sitting height. The mean body descriptor measurements for this Soldier population indicate that they were slightly heavier and taller than the Soldier population recorded in the 1988 Army Anthropometric Survey (Gordon et al., 1989).

3.4 Vision Screening

A Titmus[1] vision tester (Model OV-7M) was used to measure visual acuity (right eye, left eye, and both eyes), stereo depth perception, and color vision. Ocular dominance was measured with the unconscious sighting method of Miles (1929). To identify ocular dominance, each Soldier positioned the wide end of a truncated paper cone over both his eyes. He was then instructed to use both eyes and to focus upon the experimenter's nose. The experimenter identified each Soldier's dominant eye by observing whether his right or his left eye was aligned with the opening at the narrow end of the cone.

The results show that all Soldiers had normal color vision and that 11 had normal or corrected to normal visual acuity (20/20 Snellen equivalent or better in each eye). Eleven Soldiers displayed right eye dominance and one displayed left eye dominance. The results of the Soldiers' vision examinations are shown in appendix C.

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[1]Titmus® is a registered trademark of Titmus Optical.

Table 1. Summary anthropometric data.

Body Measurement	1988 Anthropometric Survey *Mean*[2]	Land Warrior Test Population (N=12)		
		Sample *Mean*[2]	*sd*	Percentile Range
Weight[1] (kg)	78.49	81.2	11.6	14th – 99th
Stature[1]	175.58	176.6	6.1	27th – 99th
Cervicale Height	151.94	152.4	5.8	21st – 98th
Acromial Height[1]	144.25	144.5	5.4	18th – 98th
Crotch Height	83.72	85.3	4.3	24th – 99th
Chest Breadth	32.15	31.7	2.5	2nd – 92nd
Chest Depth	24.32	26.0	2.9	18th – 99th
Neck Circumference	37.96	38.6	2.2	16th – 99th
Shoulder Circumference	117.52	119.9	7.6	2nd – 99th
Chest Circumference	99.14	98.8	7.1	3rd – 98th
Waist Circumference	88.24	88.1	7.7	14th – 98th
Waist Front Length (Omphalion)	41.45	40.4	2.1	1st – 88th
Waist Back Length (Omphalion)	46.06	47.5	1.7	5th – 74th
Sitting Height[1]	91.39	92.2	2.3	15th – 81st
Eye Height Sitting	79.20	80.4	2.3	19th – 89th
Acromial Height Sitting	59.78	59.5	2.5	13th – 93rd
Biacromial Breadth	39.70	41.6	2.5	24th – 99th
Bideltoid Breadth	49.18	49.4	2.9	2nd – 99th
Abdominal Extension Depth	23.91	23.9	3.0	5th – 99th
Bitragion Chin Arc	32.58	33.3	1.7	6th – 99th
Bitragion Coronal Arc	35.33	35.5	0.8	21st – 98th
Bitragion Crinion Arc	32.64	32.2	0.9	3rd – 82nd
Bitragion Frontal Arc	30.43	30.7	0.9	11th – 92nd
Bitragion Submandibular Arc	30.42	31.4	1.7	16th – 99th
Bitragion Subnasale Arc	29.20	30.1	1.3	10th – 99th
Head Circumference	56.77	56.9	1.7	11th – 99th
Hand Circumference	21.38	21.5	0.6	18th – 83rd
Head Breadth	15.17	15.3	0.4	24th – 95th
Head Length	19.71	19.7	0.8	5th – 98th
Menton-Sellion	12.19	11.9	0.7	1st – 91st
Ear Breadth	3.77	3.6	0.3	2nd – 89th
Hand Breadth	9.04	8.8	0.3	6th – 83rd
Hand Length	19.38	19.8	0.9	18th – 97th
Interpupillary Breadth	6.47	6.4	0.4	2nd – 97th

[1]Basic body descriptors
[2]Weight in kilograms; all other measurements are in centimeters.

3.5 Training

The Soldiers were in an MOS where carrying loads, performing mobility and portability maneuvers (movement to contact and assault maneuvers), and firing rifles and machine guns are associated with their profession (Department of Army, 1999). All participants attended a prime contractor-provided training course about the safe assembly and use of the LW system. The

training program was tailored to provide those skills necessary for the safe use of the LW system during the weapons compatibility section of testing. The test participants were instructed and shown how to wear and operate the system, as configured for these evaluations.

In addition, three noncommissioned officers in charge (NCOIC) from Fort Hood, Texas, were available for guidance and training. Subject matter experts from the U.S. Army Training and Doctrine Command System Manager-Soldier (TSM-Soldier) were on site to provide guidance and training.

During the training, Soldiers were taken on a familiarization march through the cross-country and obstacle courses and shown how to negotiate the obstacles properly and safely. After the initial marches, they practiced negotiating the obstacle course with the appropriate loads. In addition, the Soldiers were shown how to safely carry and employ all weapons and were taken to the ARL Small Arms Shooter Performance Research Facility and briefed about all standing operating procedures and safety requirements pertaining to the operation of the facility.

4. Glove Compatibility Assessment

4.1 Objectives

The objectives of the glove compatibility assessment were to

1. Determine the compatibility of the LW SCU input device with various gloves worn by Soldiers.
2. Identify LW SCU input device design characteristics that impact user performance from an HFE perspective.
3. Identify user comments and concerns regarding the LW SCU input device.

4.2 Participants

Seven Soldiers participated in this assessment. These Soldiers were a subset of the 12 Soldiers recruited from the 82nd Airborne Division, Fort Bragg, North Carolina. Because of time constraints, only seven Soldiers were available for the glove compatibility assessment.

4.3 Apparatus

1. LW Version 1.0 SCU
2. Soft keyboard
3. Special Operations Forces personal equipment advanced requirements (SPEAR) modular integrated communications helmet (MICH)

4. Helmet-mounted display (HMD)
5. Standard issue gloves: Leather utility, trigger finger mitten and liner, 25-mil nuclear, biological and chemical (NBC) and liner
6. M45 chemical protective mask
7. Miscellaneous equipment (stopwatch, questionnaire)

4.4 Procedures

4.4.1 Training

During the contractor-provided training session, Soldiers were introduced to the various components of the LW system and were trained how to use the input device to create and send messages, answer forms, and navigate through menus.

4.4.2 Assessment

Before beginning the assessment, Soldiers were given a brief explanation of the experimental procedures. They then donned the LW system and began the experiment. During the experiment, the soft keyboard was displayed on the HMD, and the text entry task was attached to the wall in front of the Soldier at eye level. Each Soldier used the SCU to perform the task while bare handed and while wearing each of the different gloves. Soldiers were instructed that accuracy was important and that they should correct any errors. Task completion time was measured in seconds. After completing the task in each condition, they completed the questionnaire. Following completion of the questionnaire, Soldiers donned a different glove and performed a different text entry task. Each of the text entry tasks consisted of 60 characters (see figure 2). This procedure was followed until each Soldier completed all of the glove conditions. In addition, three Soldiers performed the text entry task bare handed in a darkened room, bare handed while wearing the M45 mask, and while wearing the 25-mil NBC glove and M45 mask.

fresh sweet 348 paper law going flower 9 free 7558 cat happy

Figure 2. Sample alphanumeric text entry task.

4.5 Experimental Design

4.5.1 Independent Variables

The independent variables were the various gloves and the M45 chemical protective mask.

4.5.2 Dependent Variables

The dependent variables were

1. Time to complete the alphanumeric text entry task and
2. Responses from questionnaires.

4.5.3 Matrix

A within-subjects design was used. Each subject was exposed to all glove conditions. The order of glove presentation is shown in table 2.

Table 2. Glove presentation order.

Soldier ID Number	Glove Order				
4, 7	4	1	3	2	5
5, 11	1	2	4	3	5
6, 12	2	3	1	4	5
8	3	4	2	1	5

1 = Bare hand
2 = NBC
3 = Trigger finger mitten
4 = Leather utility
5 = Bare hand (dark room)

4.5.4 Subjective Measures

A questionnaire was developed to obtain the Soldiers' opinions about the physical effort required to use the LW input device and the ease with which they could enter text and numbers (see appendix D). Participants completed the questionnaire after they performed the text entry task for each glove condition. They were instructed to select the response that best represented their opinion about the input device and were encouraged to provide additional feedback or comments at the bottom of the questionnaire.

4.6 Results

4.6.1 Alphanumeric Task Completion Time

The task completion time data was used to perform a repeated measures analysis of variance (ANOVA). The results showed a main effect of glove, $F(4,24) = 11.28$, $p < .0001$. Tukey's honestly significant difference (HSD) *post hoc* test revealed that task completion time when the trigger finger mitten was worn was significantly slower than the bare hand and other glove conditions. Performance of the text entry task was 44.4% slower than when Soldiers were bare handed and wearing the 25-mil glove and 41.4% slower than with the leather utility glove. The trigger finger mitten accounted for approximately 68% of the variance in task completion time. Observations made during the evaluation indicate that when participants wore the trigger finger mitten, they resorted to using both hands to complete the task. Mean task completion time for each glove is shown in figure 3.

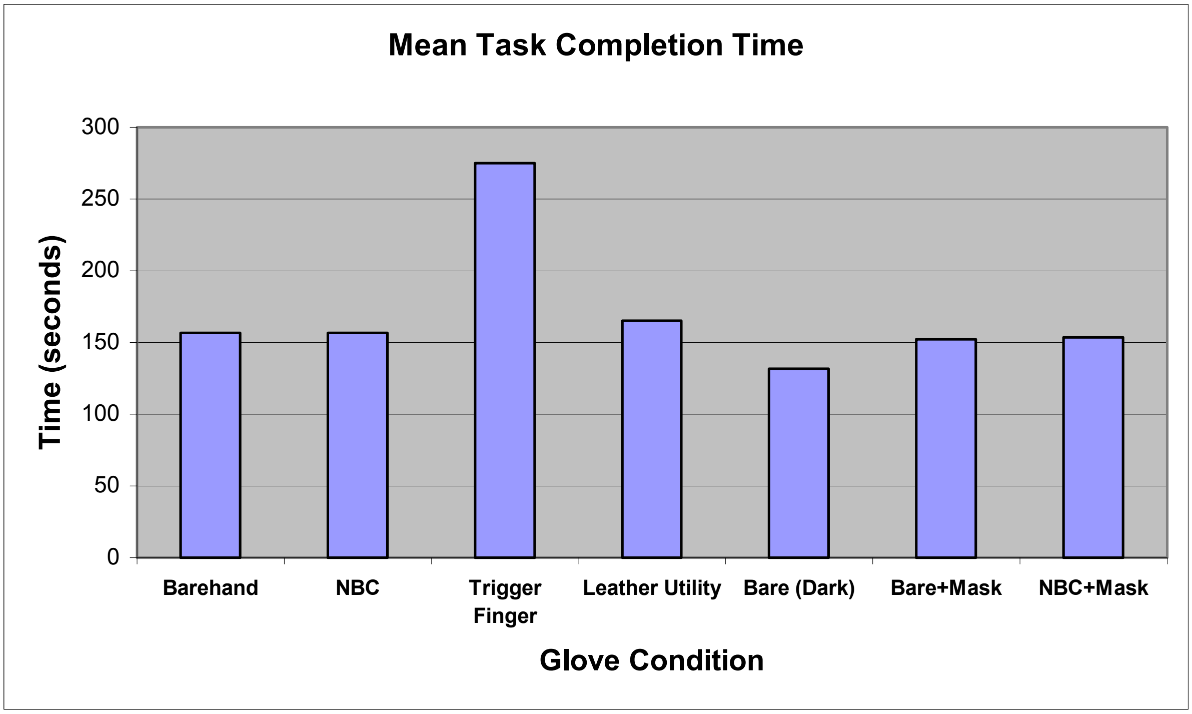

Figure 3. Mean completion time for text entry task.

Three participants also performed additional trials while bare handed and wearing the M45 mask and while wearing the butyl rubber chemical protective gloves and M45 mask. These trials were not part of the original plan but were added in order to determine if the mask would impact performance. Because of the additional time required, only three Soldiers were available to participate. Since only three participants performed the additional trials, an ANOVA was not performed for these data. Mean task completion times for the bare hand with M45 mask and butyl rubber chemical protective gloves with M45 mask are 152.04 and 153.03 seconds, respectively. Mean completion time data for all trials are shown in appendix E.

4.6.2 Subjective Measures

Each Solider was given a questionnaire after he completed the text entry task for each glove condition. The questionnaire used a 5-point Likert scale consisting of six statements covering issues of effort, fatigue, comfort, and overall usability. Question 1 addresses the ease of entering text while the different gloves are worn. Questions 2 through 5 address fatigue and comfort. Question 6 concerns the overall usability of the SCU with the gloves. Results indicate that the trigger finger mitten made the text entry task more difficult to perform, and participants thought that the SCU was more difficult to use when they wore the trigger finger mitten. Subjective ratings for the trials performed while Soldiers wore the mask were consistent with the no-mask trials, indicating that participants did not think the mask affected their performance, which is consistent with the objective data and additional comments noted by participants on the bottom of the questionnaire. Results of the questionnaire are shown in figures 4 through 9. The means and standard deviations for these ratings are shown in appendix F.

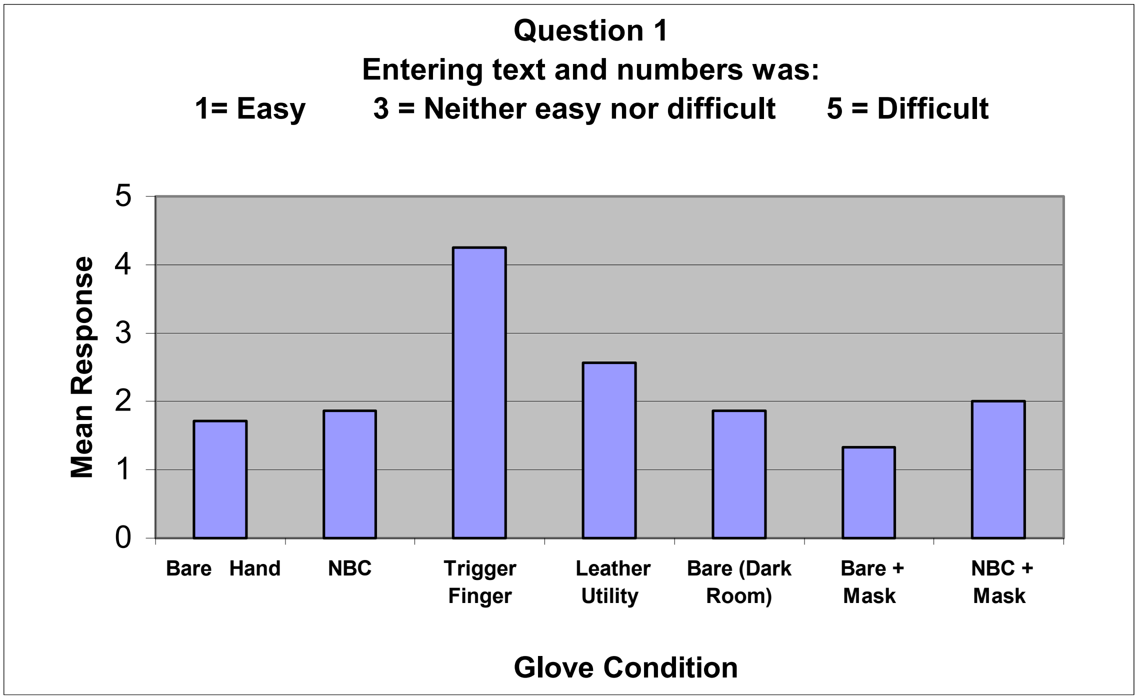

Figure 4. Mean responses for question 1.

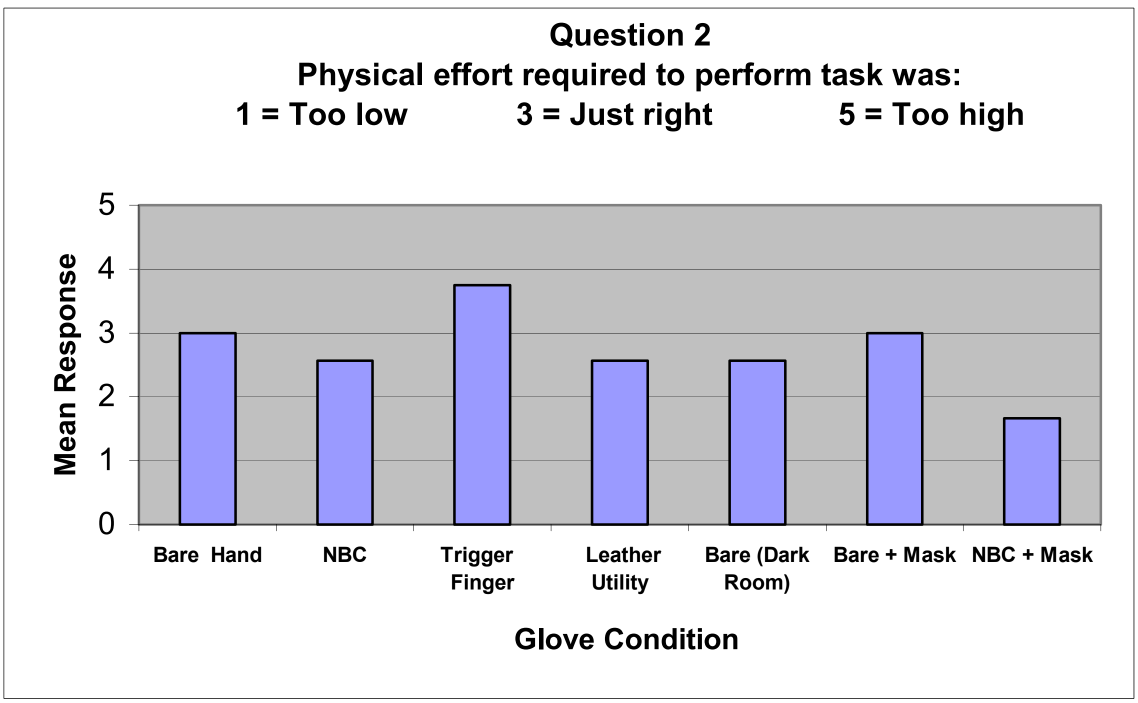

Figure 5. Mean responses for question 2.

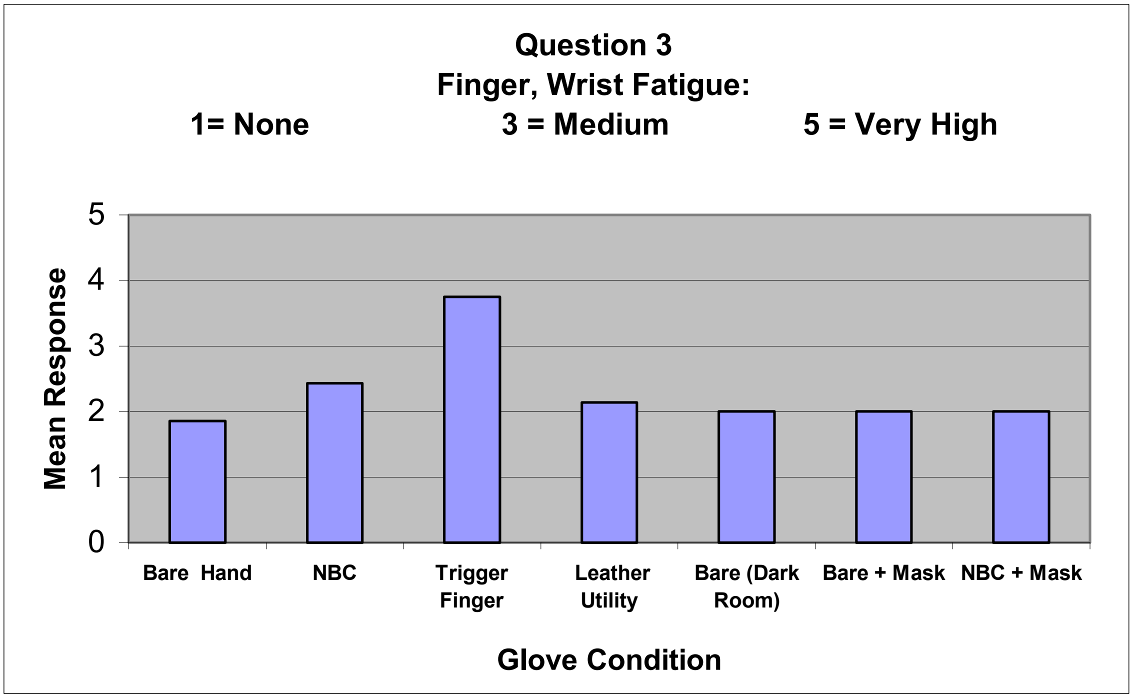

Figure 6. Mean responses for question 3.

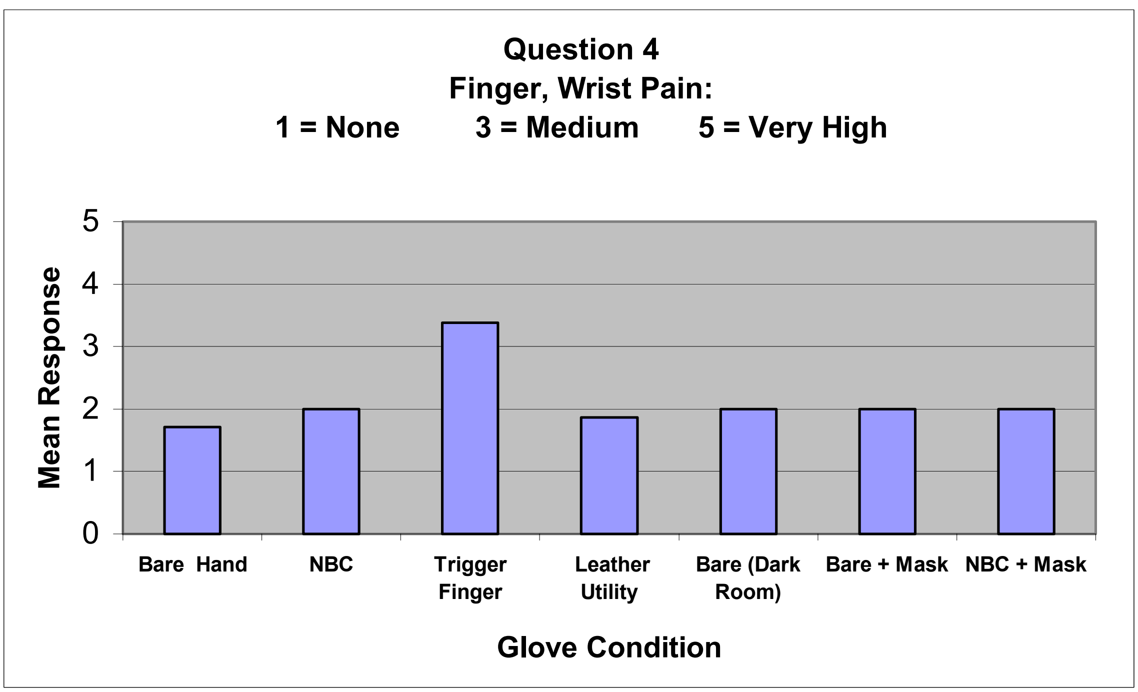

Figure 7. Mean responses for question 4.

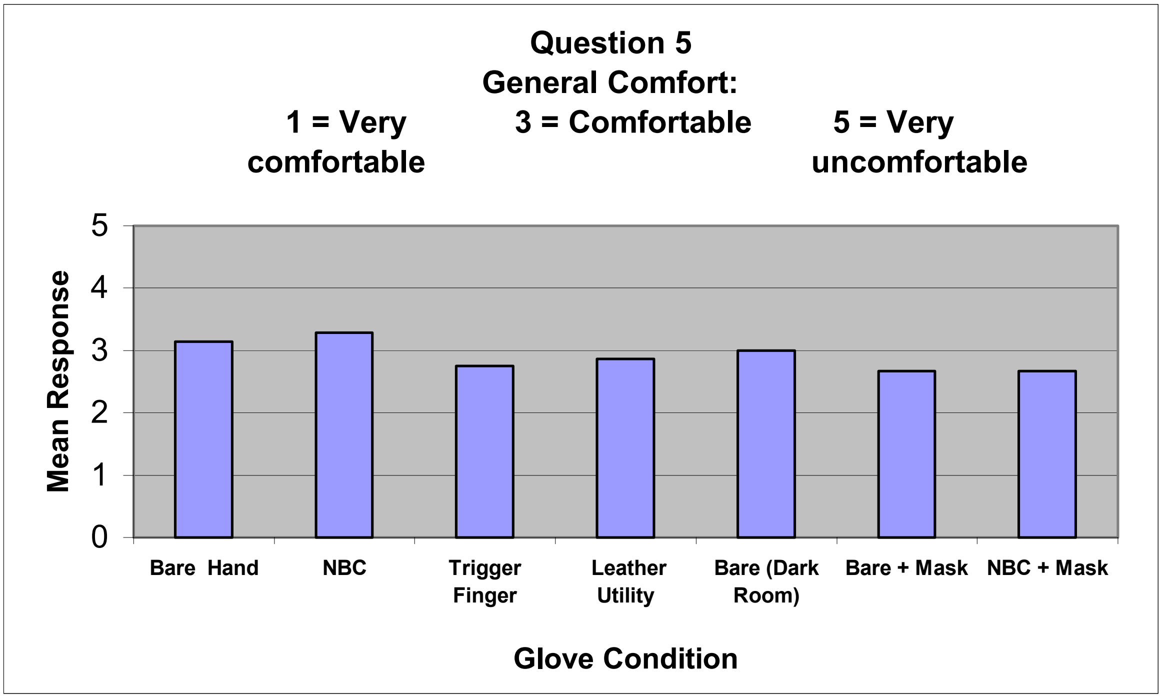

Figure 8. Mean responses for question 5.

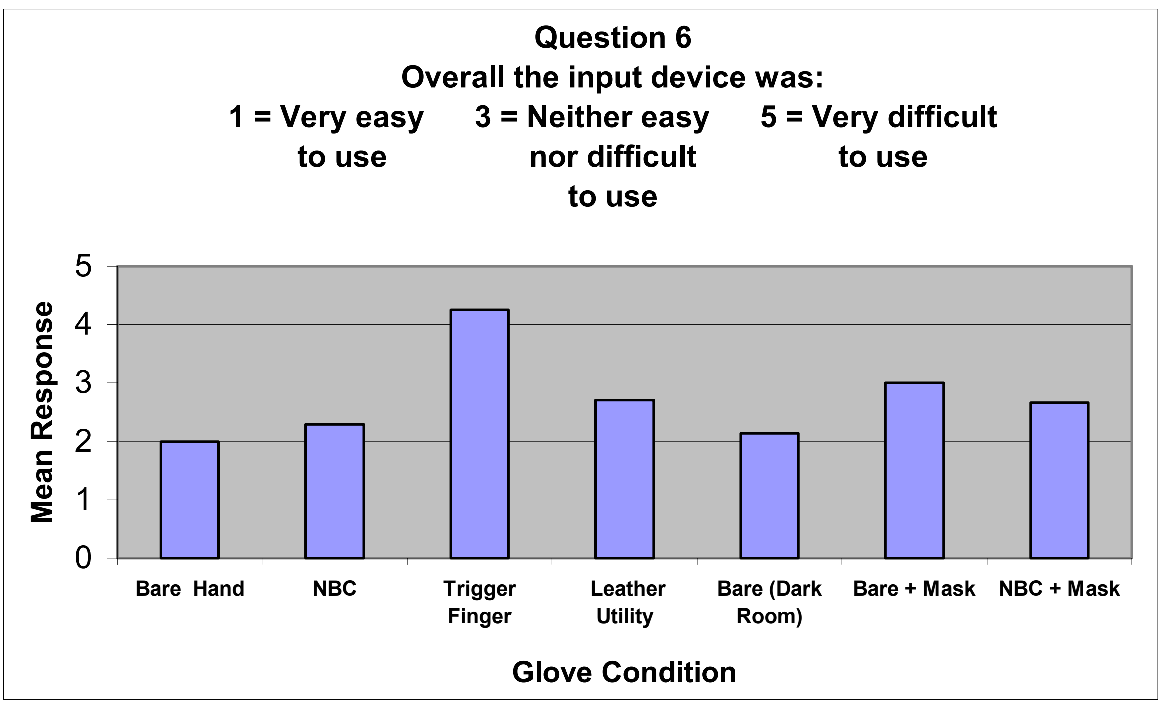

Figure 9. Mean responses for question 6.

4.7 Discussion

As mentioned previously, there were three objectives of the glove compatibility assessment. The first was to determine the compatibility of the LW input device with various gloves worn by Soldiers. Objective and subjective data collected during the assessment indicate that none of the Soldiers had difficulties completing the text entry task while bare handed, wearing the butyl rubber glove or the leather utility glove. However, wearing the trigger finger mitten resulted in significantly slower task completion times, which indicated that thick, bulky gloves may not be suitable for use with wearable input devices. The thickness of the trigger finger mitten made it difficult for Soldiers to feel the control buttons on the input device, which resulted in the use of two hands to complete the text entry task. Soldiers became very frustrated while wearing the trigger finger mitten and commented that if they were ever in a situation that required them to wear the mitten and use the input device, they would remove the mitten and use their bare hands. Further evaluations should be conducted to determine if other types of input devices are more suitable for use with bulky gloves.

The second objective was to identify any input device design considerations that impact user performance. The cursor control portion of the input device is a small joystick mounted in a shallow casing, vulnerable to dirt collection inside. During the assessment, several Soldiers commented that the cursor control "stuck," which made it difficult to move the cursor around the screen. This is an important issue when one is considering that the input device will be exposed to different environmental conditions (i.e., dirt, moisture). Placing a sleeve or covering over the exposed areas of the input device may help alleviate dirt accumulation inside the device. Another alternative may be to use an input device that is fully enclosed.

The third objective was to identify user comments and concerns regarding the LW input device. Subjective data obtained from participants indicate that the trigger finger mitten made it difficult to perform the text entry task, required more physical effort to perform the task, and resulted in more finger and wrist fatigue and pain than the other gloves. Overall, participants thought that the input device was difficult to use when they wore the trigger finger mitten. Additional comments from participants indicated that their hands began cramping when they wore the trigger finger mitten. It is interesting that a few participants thought that the physical effort required was too low when the NBC glove was worn. The NBC glove is made of a soft butyl rubber, which may have enabled the participants to get a better grip on the device, thereby reducing the amount of physical effort required to use the device.

Eyestrain from looking at the HMD was another concern noted by participants. Participants also commented that it was difficult to see the HMD when they wore the M45 mask because the edges of the mask made the images on the HMD blurry. To alleviate this problem, participants held the HMD in place, which means that both hands were used to perform the text entry task. Although this was not reflected in the task completion time data, using both hands would have serious implications for a Soldier in a combat situation.

The results of the glove compatibility assessment indicate that the standard issue NBC and leather utility glove did not significantly impact task performance with the LW input device, thus indicating that the input device may be appropriate for the LW system. However, because of input device design characteristics, usage may be limited to rather benign environments and those that do not require bulky hand protection. Although the mask did not significantly impact task performance time, compatibility issues with the mask should be addressed. A better interface between the HMD and mask is needed. Other display technologies, such as hand-held displays, should be considered.

Participants also noted that the backspace and clear buttons are situated next to each other on the soft keyboard. One participant indicated that he inadvertently pressed the clear button instead of the backspace button and lost all the text that had been entered. Participants suggested that the backspace and clear buttons should be situated on opposite sides of the soft keyboard.

4.8 Recommendations

1. Reposition delete and backspace keys on soft keyboard so that they are not next to each other.
2. The mouse input device should be modified (i.e., a collar should be placed around the device) to alleviate problem of dirt accumulation. Alternate input devices should also be investigated.
3. The HMD should be modified so that it rests against the lens of a chemical protective mask. HMDs that offer better resolution may help alleviate eyestrain. Other display technologies, such as hand-held displays, should be investigated as alternatives to the HMD.

5. Shooting Performance Assessment

5.1 Objectives

The objectives of the shooting performance assessment were to

1. Determine the ability of the LW Soldier to accurately aim and fire weapons in day and night conditions.
2. Determine the ability of the Soldier to aim and fire the weapon using the LW DVS camera or thermal sight when viewed through the HMD.
3. Determine if there are any compatibility issues between the LW system and the M4 carbine or M249 SAW systems.

5.2 Apparatus

1. LW System version 1.0
2. M4 carbine
3. M249 SAW
4. M68 reflex sight, also called the CCO
5. DVS
6. M145 machine gun optic
7. Medium thermal weapon sight (MTWS)
8. MTWS (Omni version)

5.3 Procedures

5.3.1 Training

All Soldiers had previously qualified for all weapons that they shot during this assessment. Soldiers received one day of weapon training and range familiarization. This training was conducted by Omega Training Group, Inc.

5.3.2 Experimental Trials

Before beginning the assessment, Soldiers were given a brief explanation of the experimental procedures. The weapons were boresighted and "zeroed" by the Soldiers. A common zero was used since individual differences in CCO zero and DVS zero are thought to be minimal and should not affect performance for the ranges examined. They then donned the LW system and began the experiment. Soldiers received one training trial with every weapon before starting the experimental trials.

5.3.2.1 M4 Daylight Firing. Twelve Soldiers participated in the M4 daylight firing assessment. Soldiers used the M4 with the M68 reflex sight and the DVS viewed on the HMD, to fire at targets at ranges of 50, 100, 150, 200, 250, and 300 meters. These targets had exposure times of 3, 5, and 8 seconds. Soldiers fired an 18-target scenario from the standing unsupported, kneeling unsupported, foxhole supported, and prone unsupported firing positions.

5.3.2.2 M4 Reduced Exposure Firing. Eight Soldiers participated in the M4 reduced exposure firing assessment. Soldiers used the M4 with the DVS viewed on the HMD, to fire at targets at ranges of 50, 100, 150, 200, 250, and 300 meters. These targets had exposure times of 8, 12, and 16 seconds. Soldiers fired the weapons from behind a wall in both the standing and kneeling firing positions. Soldiers fired around the left side of the wall, right side of the wall, and over the top of the wall while trying to expose as little of their bodies as possible. Soldiers were given a

full 30-round magazine and fired at an 18-target scenario. Soldiers were allowed to fire more than one round at a single target.

5.3.2.3 M4 Night Firing. Eight Soldiers participated in the M4 night firing assessment. Soldiers used the M4 with the MTWS directly and the MTWS viewed on the HMD, to fire at targets at ranges of 50, 100, 150, 200, 250, and 300 meters. These targets had exposure times of 5 and 8 seconds. Soldiers fired from the standing unsupported and foxhole supported firing positions. Soldiers were given a full 30-round magazine and fired at an 18-target scenario. Soldiers were allowed to fire more than one round at a single target. The targets were heated to provide realistic thermal signatures.

5.3.2.4 M249 Day Firing. Three Soldiers participated in the M249 daylight firing assessment. Soldiers used the M249 SAW with the M145 machine gun optic and the DVS viewed on the HMD, to fire at targets at ranges of 200, 300, 400, and 500 meters. These targets had exposure times of 6, 8, and 10 seconds. Soldiers fired from the foxhole and prone firing positions. Soldiers were given a 200-round belt and fired at a 12-target scenario.

5.3.2.5 M249 Night Firing. Three Soldiers participated in the M249 night firing assessment. Soldiers used the M249 SAW with the MTWS (Omni version) viewed directly and on the HMD, to fire at targets at ranges of 200, 300, 400, and 500 meters. These targets had exposure times of 6, 8, and 10 seconds. Soldiers fired from the foxhole and prone firing positions. Soldiers were given a 200-round belt and fired at a 12-target scenario. This assessment was performed during the day with the electrically heated targets. The Soldier's non-aiming eye was covered to require the Soldier to use the thermal sight to acquire and aim at targets.

5.4 Experimental Design

5.4.1 Independent Variables

5.4.1.1 M4 Daylight Firing. The independent variables were weapon sight (CCO and DVS), firing position (standing unsupported, kneeling unsupported, foxhole supported, and prone unsupported), target exposure time (3, 5, and 8 seconds), and range (50, 100, 150, 200, 250, and 300 meters).

5.4.1.2 M4 Reduced Exposure Firing. The independent variables were firing position (standing and kneeling), weapon position (left side of wall, right side of wall, over top of wall), target exposure time (8, 12, and 16 seconds), and target range (50, 100, 150, 200, 250, and 300 meters).

5.4.1.3 M4 Night Firing. The independent variables were weapon sight (MTWS direct view and MTWS shown on the HMD), firing position (foxhole supported and standing unsupported), target exposure time (5 and 8 seconds), and target range (50, 100, 150, 200, 250, and 300 meters).

5.4.1.4 M249 Day Firing. The independent variables were weapon sight sight (DVS and M145), firing position (foxhole supported and prone unsupported), target exposure time (6, 8, and 10 seconds), and target range (200, 300, 400, and 500 meters).

5.4.1.5 M249 Night Firing. The independent variables were weapon sight (MTWS direct view and MTWS) shown on the HMD), firing position (foxhole supported and prone unsupported), target exposure time (6, 8, and 10 seconds), and target range (200, 300, 400, and 500 meters).

5.4.2 Dependent Variables

The dependent variable for each of the shooting assessments was target hit percentage (targets hit divided by targets presented).

5.4.3 Evaluation Matrix

For each evaluation, a repeated measures design was used to expose each subject to each condition. The presentation of the conditions was counterbalanced to reduce any practice or order effects.

5.5 Results

Mean shooting data are presented in appendix G.

5.5.1 M4 Daylight Firing

In the M4 daylight firing conditions, the mean overall hit percentage was 50%. The mean hit percentage was 59% with the M68 reflex sight and 40% with the DVS. The hit percentage data were used to perform a repeated measures ANOVA. The results showed that the hit rate for the M68 reflex sight was significantly ($F_{1,11} = 39.2$ $p < .0001$) higher than for the DVS.

The mean hit percentage for each firing position is shown in figure 10. An ANOVA showed significant differences ($F_{1,11} = 39.2$ $p < .0001$) between the different firing positions. *Post hoc* Scheffé tests revealed that the hit percentages in the foxhole and prone firing positions were significantly higher than in the standing firing position. Also, hit percentages in the foxhole firing position were significantly higher than in the kneeling position.

The mean hit percentage data for the Sight x Exposure Time interaction is presented in figure 11. A significant Sight x Exposure Time interaction was found on the hit percentage data ($F_{2,22} = 8.05$ $p = .002$). *Post hoc* Scheffé tests showed that the hit percentage difference between sights was greater for the 3-second targets than for the targets with longer exposure times.

The mean Sight x Target Range interaction for hit percentage data is shown in figure 12. The ANOVA failed to show a significant effect for this interaction.

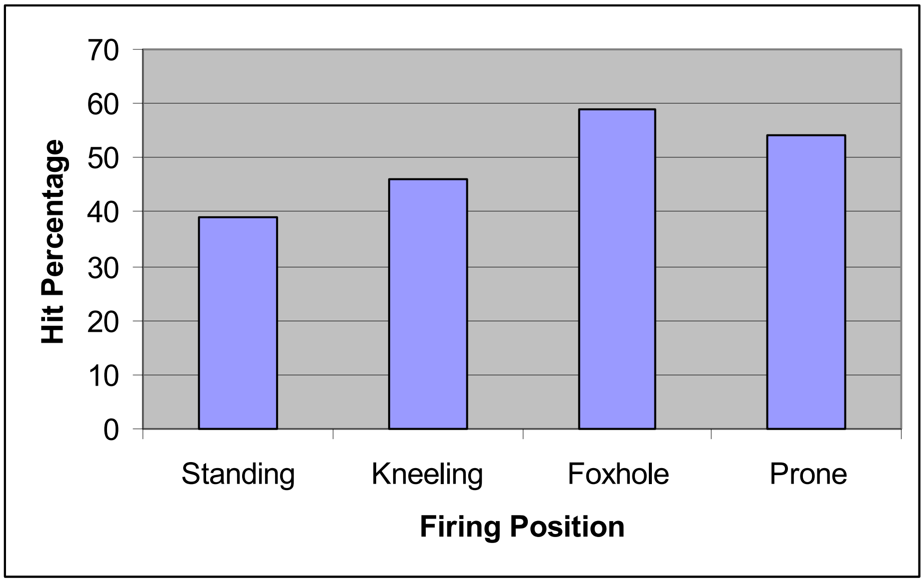

Figure 10. Hit percentage for each firing position for M4 daylight firing.

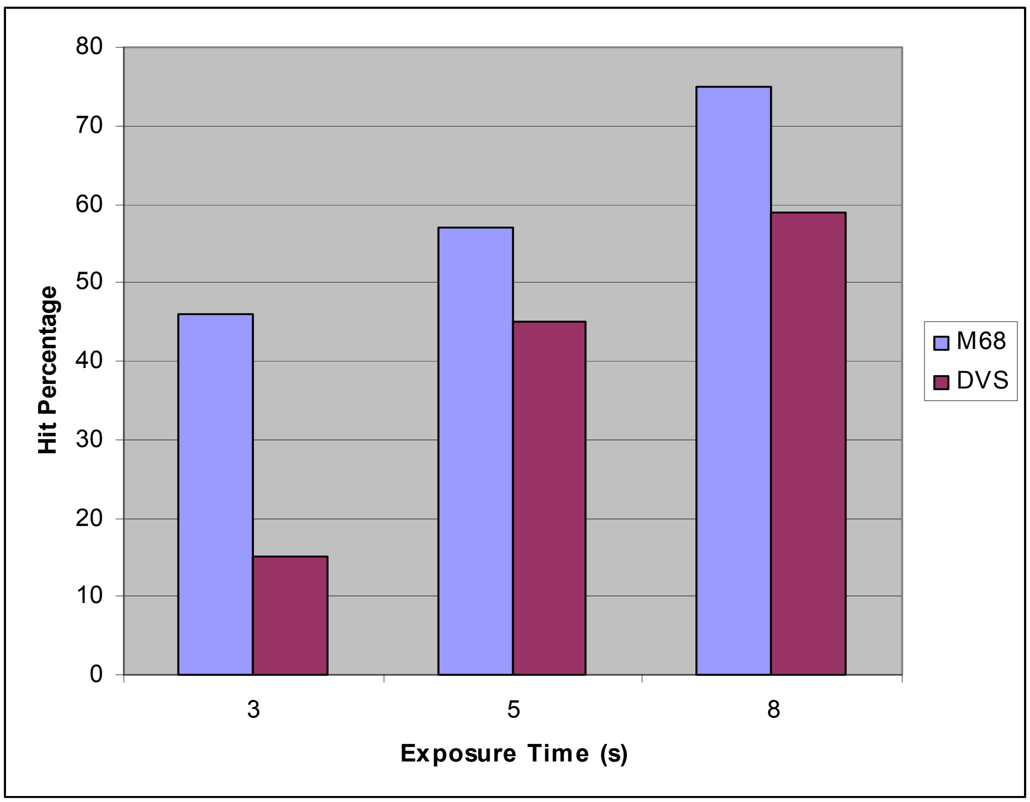

Figure 11. Sight x Target Exposure Time interaction for M4 daylight hit percentage data.

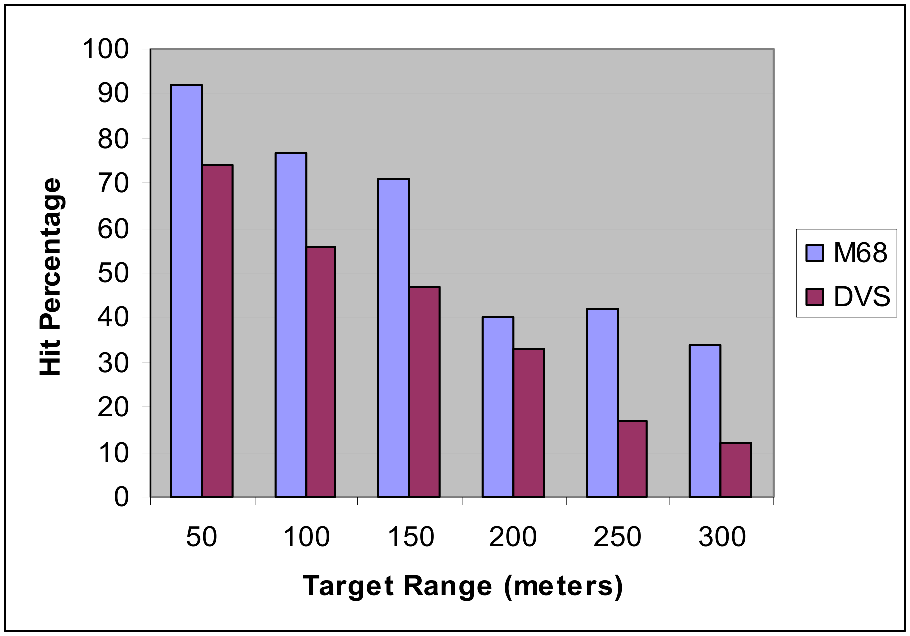

Figure 12. Sight x Target Range interaction for M4 daylight hit percentage data. (This effect failed to reach significance at the .05 level.)

5.5.2 M4 Reduced Exposure Firing

In the M4 reduced exposure firing conditions, the mean overall hit percentage was 36%. The mean hit percentage was 38% in the standing firing position and 34% in the kneeling firing position. The mean hit percentages for weapon position (right side, left side, overhead) and firing position are presented in figure 13. Repeated measures ANOVAs were performed on the hit data. The main effects of firing position and weapon position failed to reach significance.

The ANOVA on reduced exposure firing hit data showed a significant interaction effect of Target Exposure Time x Range ($F_{10,70} = 3.58$ $p < .01$) and is shown in figure 14. The main effects of target exposure time ($F_{2,14} = 33.4$ $p < .0001$) and target range ($F_{5,35} = 37.1$ $p < .0001$) were also significant.

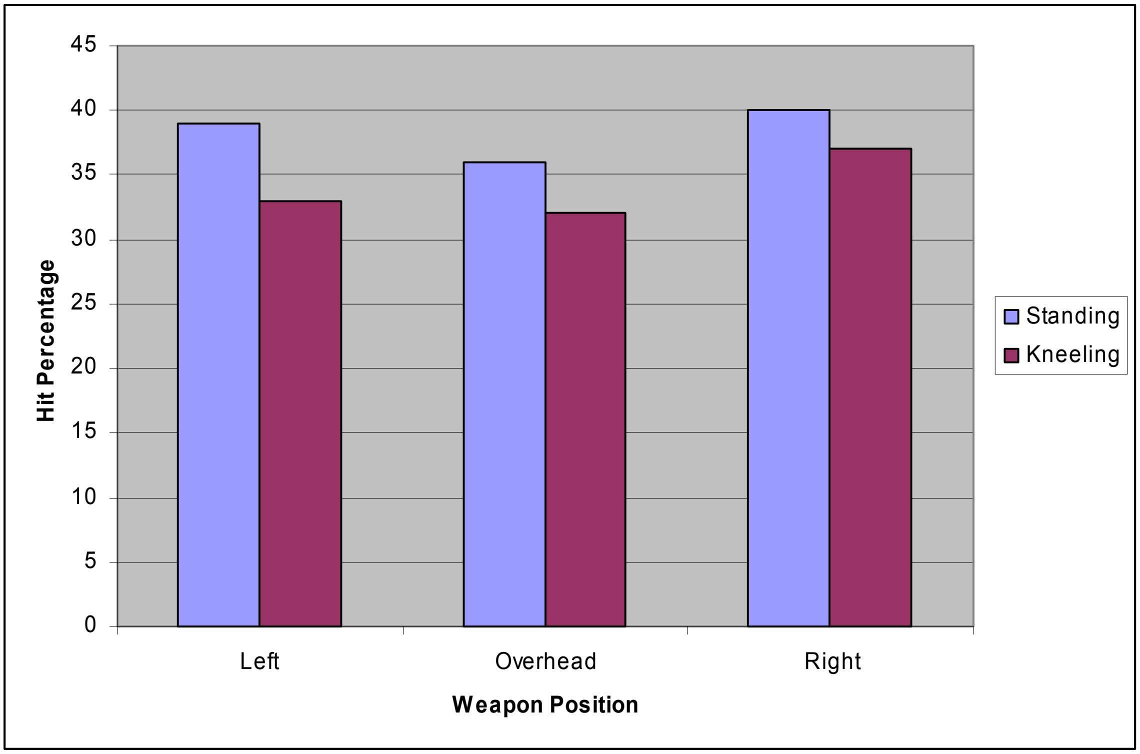

Figure 13. Firing Position x Weapon Position interaction on hit percentage for reduced exposure firing. (This effect failed to reach significance at the .05 level.)

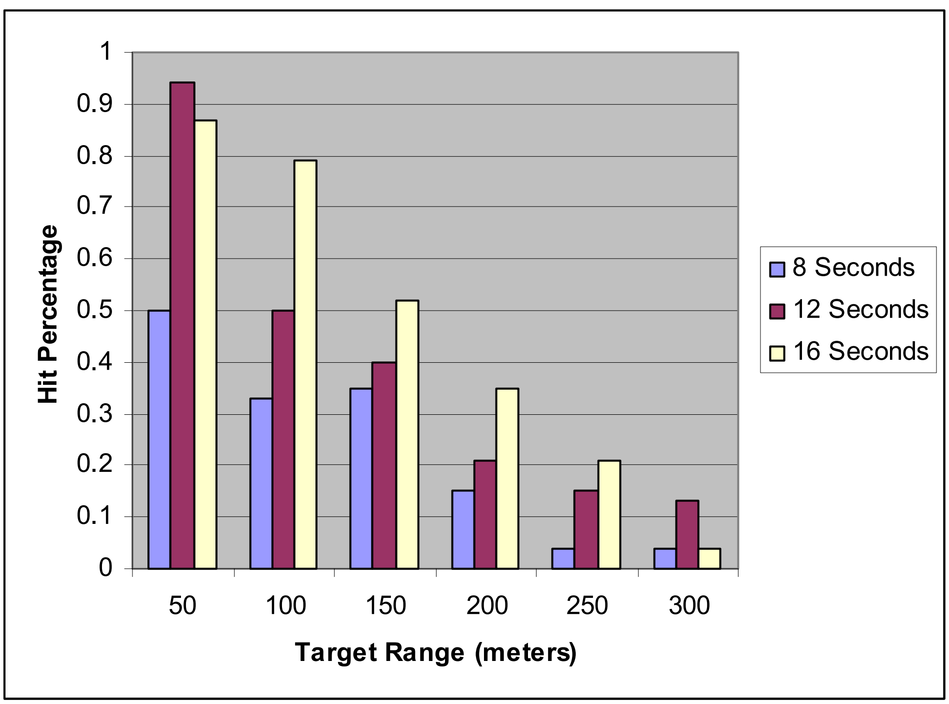

Figure 14. Significant Target Range x Target Exposure Time interaction on hit percentage for reduced exposure firing.

5.5.3 M4 Night Firing

In the M4 night firing conditions, the mean overall hit percentage was 24%. The mean hit percentage was 36% with the MTWS and 12% with the MTWS shown on the HMD. The hit percentage data were used to perform a repeated measures ANOVA. The results showed that the hit rate for the MTWS direct view was significantly ($F_{1,6} = 13.8$ $p = .01$) higher than for the MTWS shown on the HMD.

The ANOVA on M4 night hit data showed a significant interaction effect of Target Exposure Time x Range ($F_{5,30} = 8.56$ $p < .0001$) and are shown in figure 15. The main effects of target exposure time ($F_{1,6} = 50.7$ $p < .0001$) and target range ($F_{5,30} = 27.2$ $p < .0001$) were also significant.

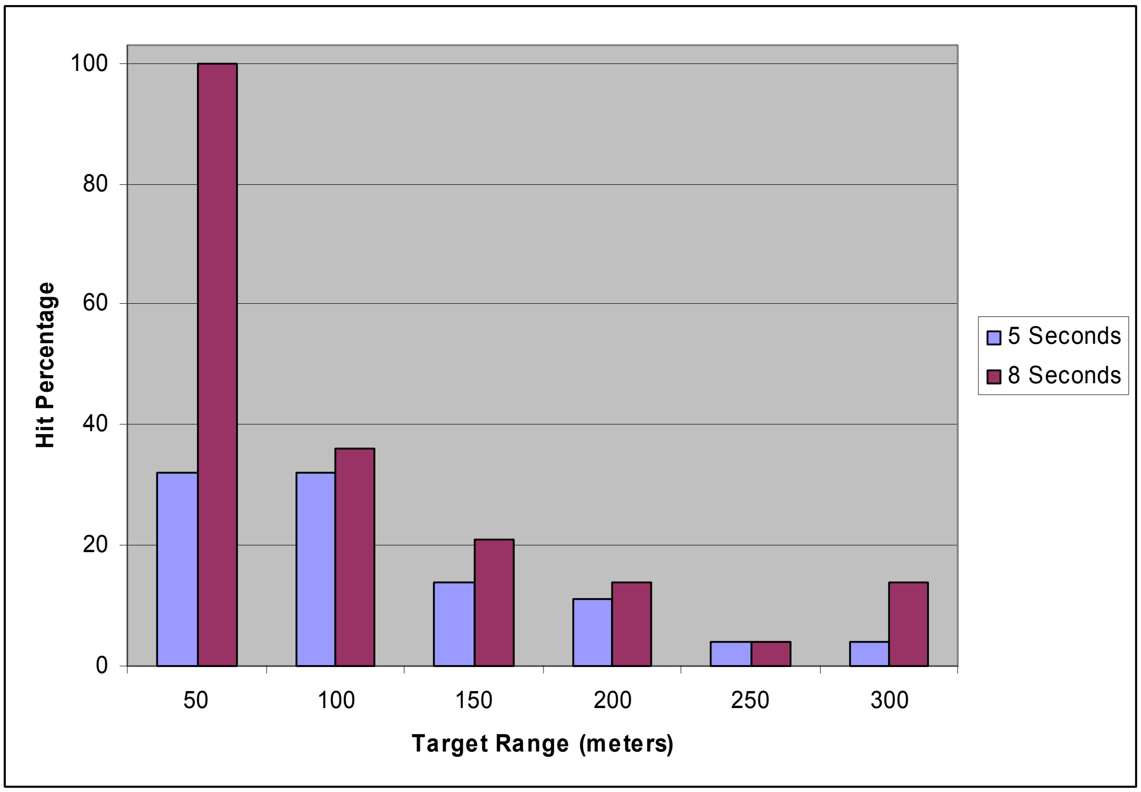

Figure 15. Significant Target Range x Target Exposure Time interaction on hit percentage for M4 night firing.

An ANOVA on M4 night hit data also showed a significant interaction effect of Sight x Range ($F_{5,30} = 3.49$ $p = .013$) and is shown in figure 16.

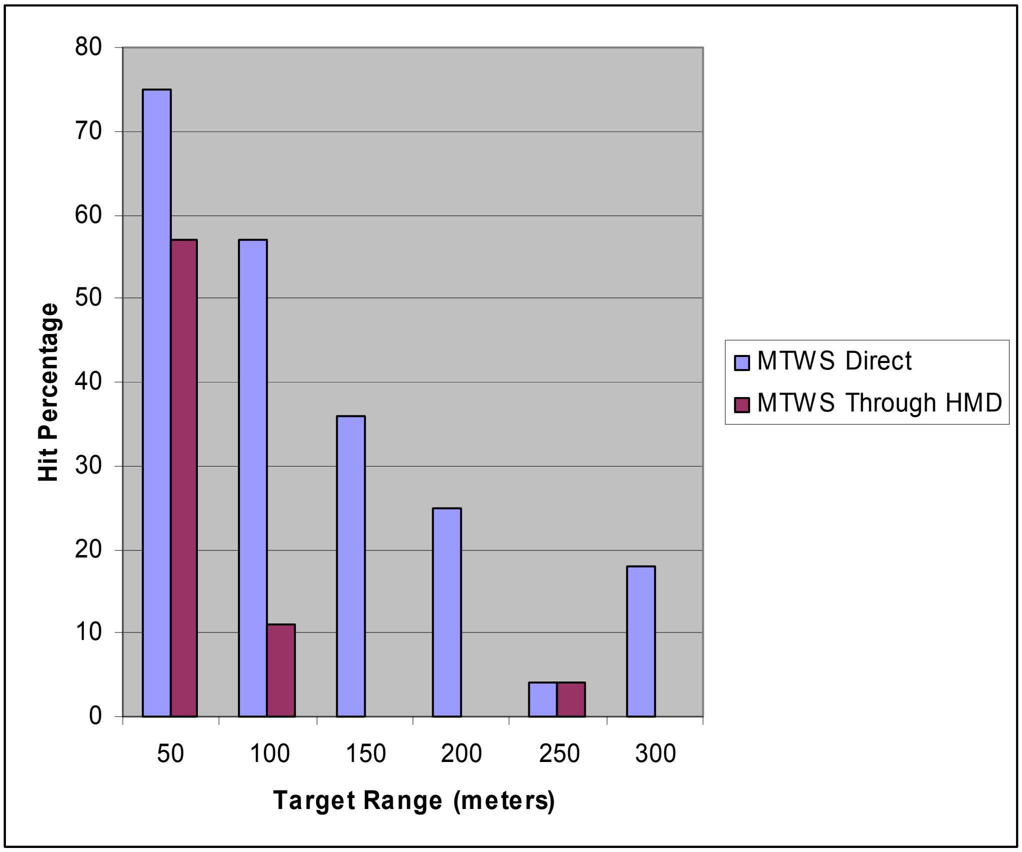

Figure 16. Significant Sight x Target Range interaction on hit percentage for M4 night firing.

5.5.4 M249 Day Firing

In the M249 day firing conditions, the mean overall hit percentage was 38%. The mean hit percentage was 47% with the M145 machine gun optic and 28% with the DVS shown on the HMD. Since there were only three subjects in these trials, ANOVAs were not performed for these data. The Sight x Target Exposure Time interaction for hit percentage data is presented in figure 17, and the Sight x Range interaction for mean hit data is provided in figure 18.

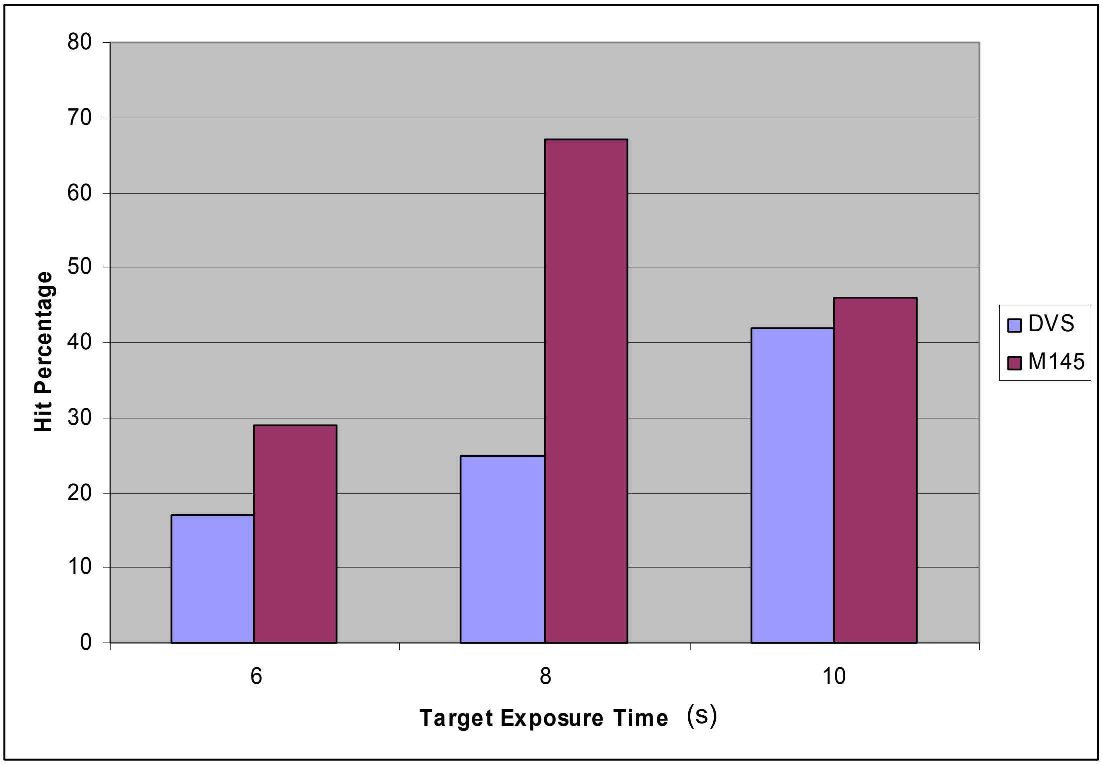

Figure 17. M249 day firing mean hit percentages for Sight x Target Exposure Time interaction.

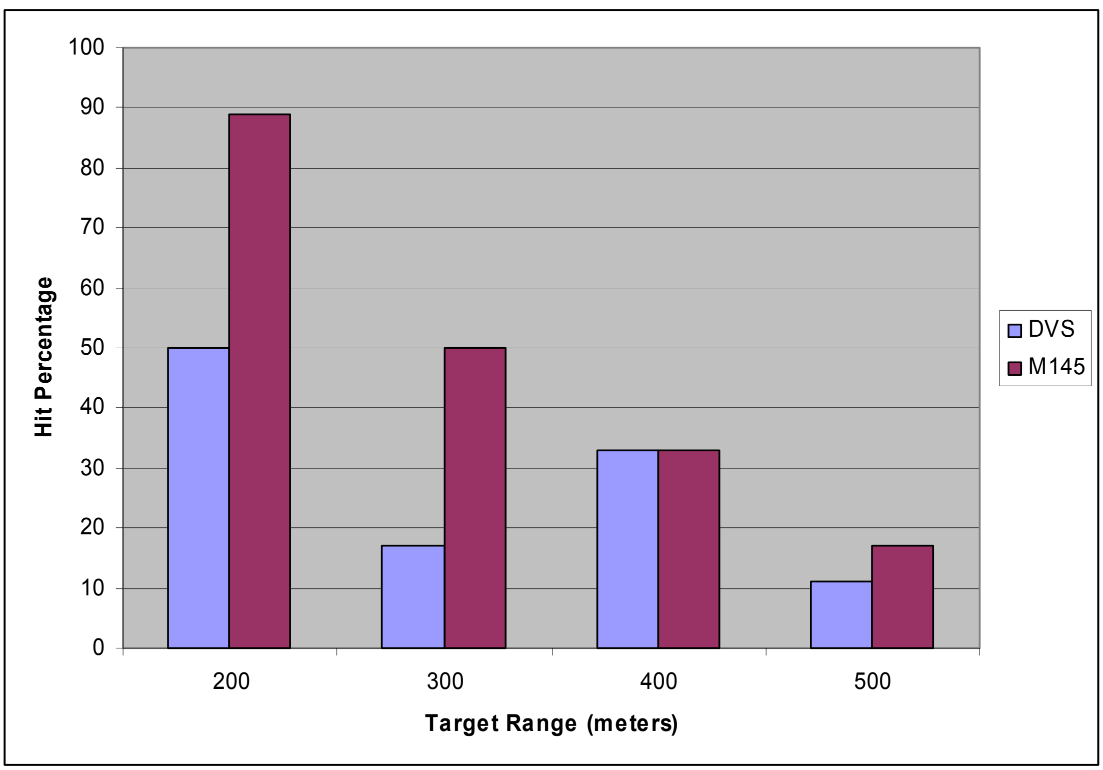

Figure 18. M249 day firing mean hit percentages for Sight x Target Range interaction.

5.5.5 M249 Night Firing

In the M249 night firing conditions, the mean overall hit percentage was 41%. The mean hit percentage was 46% with the MTWS direct view and 36% with the MTWS through the HMD. Since there were only three subjects in these trials, ANOVAs were not performed for these data. The Sight x Target Exposure Time interaction for hit percentage data is presented in figure 19, and the Sight x Range interaction for hit percentage data is provided in figure 20.

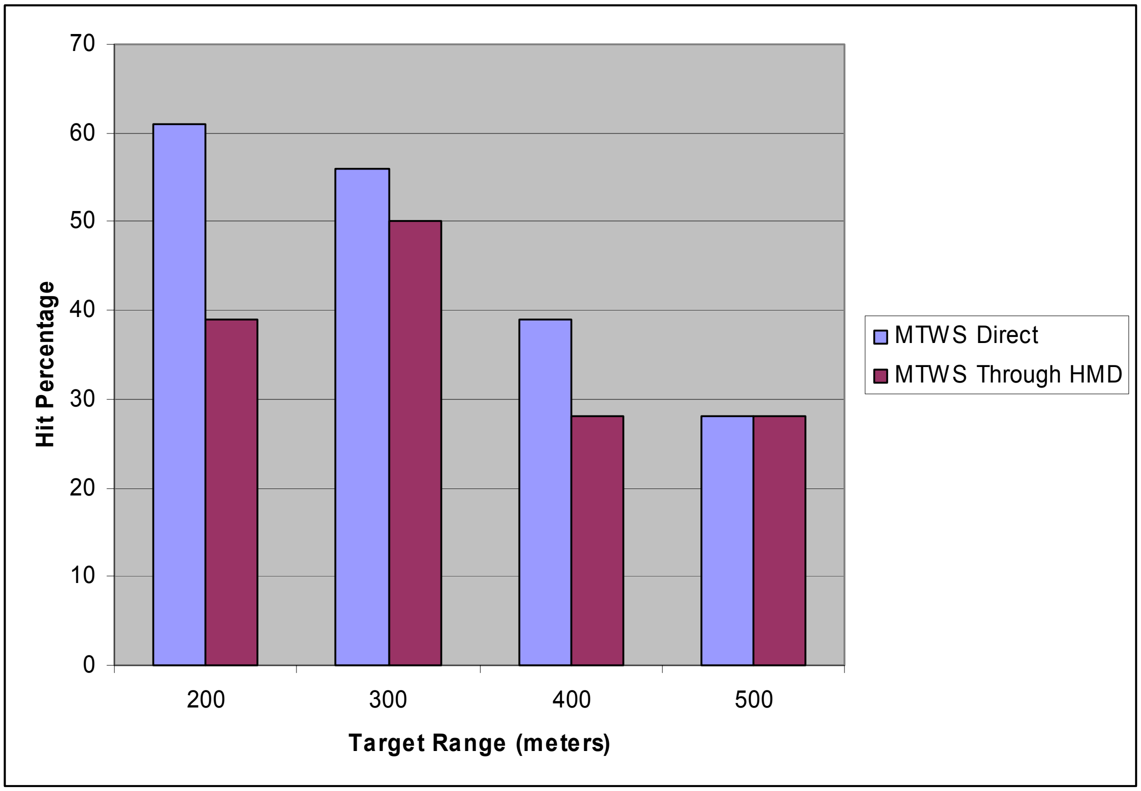

Figure 19. M249 night firing mean hit percentages for Sight x Target Range interaction.

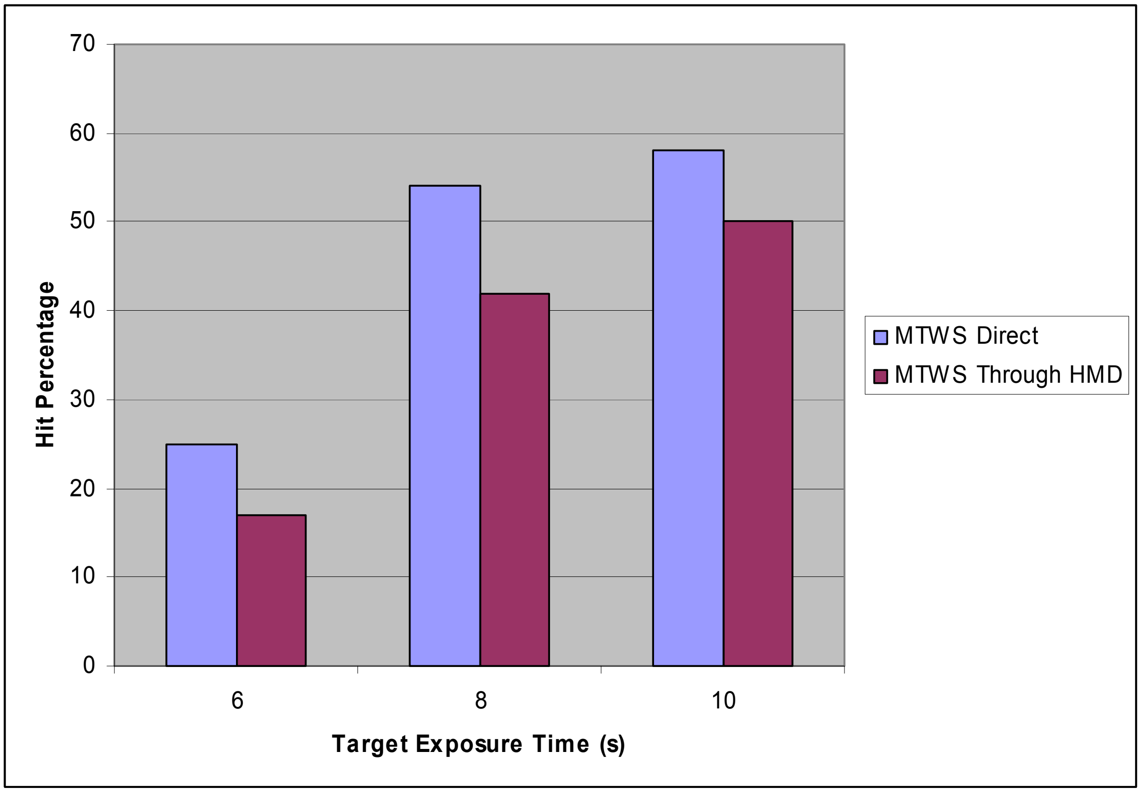

Figure 20. M249 night firing mean hit percentages for Sight x Target Exposure Time interaction.

5.6 Discussion

In general, Soldiers performed better when using current equipment than when firing with the HMD to acquire and aim at targets. The reasons for the differences may be different for the different evaluations. In the day firing evaluations, the loss of field of view (FOV), resolution, and contrast when a camera system was used may have affected the performance. In the night evaluations, the loss of image quality for the HMD viewed systems or the fact that Soldiers are not as familiar with off-bore firing may have contributed to the degraded performance.

5.6.1 M4 Daylight Firing

The M4 day firing data show that Soldiers performed better when firing with the M68 reflex sight than when firing with the DVS. This difference is greatest at the shortest target exposure time. This decrease in performance when the DVS was used is not unexpected for these ranges. Acquiring targets through a sensor with a small FOV will take Soldiers longer. The resolution loss of viewing through a camera system may also affect performance.

5.6.2 M4 Reduced Exposure Firing

The reduced exposure firing assessment was used to demonstrate a capability. Soldiers were able to hit targets when viewing through a camera system and without exposing much of their bodies. The data also showed that there was no difference in where Soldiers held the weapon

(right side of wall, left side of wall, or over the top of the wall). The overall hit percentage for targets from 50 to 300 meters was 36%. The analyses also showed that to hit these targets, Soldiers needed a significant amount of time and the targets had to be relatively close. Soldiers performed much better for the 12- and 16-second target exposures than for the 8-second exposure targets. This would suggest that the time to acquire, aim, and fire at targets takes longer than 8 seconds in many cases.

One safety issue was noted during firing in the reduced exposure assessment. When Soldiers fired around the left side of the wall, the ejected cartridges occasionally flew back toward their faces.

5.6.3 M4 Night Firing

In the M4 night firing assessment, Soldiers had much more difficulty firing with the thermal image presented on the HMD than when they looked into the MTWS. This may have been attributable to some problems with the "video out" on the MTWS. The image presented to the HMD was not nearly as good as seen when one looked directly into the MTWS.

5.6.4 M4 Day Firing

In the M249 day firing assessment, Soldiers performed better when using the M145 machine gun optic than when they used the DVS, particularly at the shorter target exposure times. The direct view optic of the M145 may have provided a clearer picture, allowing for easier target acquisition.

5.6.5 M249 Night Firing

In the M249 night firing assessment, Soldiers performed better when using the MTWS in the direct view mode than when the image was viewed on the HMD. In this assessment, the problems of the MTWS output to the HMD had been resolved and the image on the HMD looked very similar to that shown on the MTWS display. The MTWS Omni version was used in this assessment.

5.7 Recommendations

Future work should be conducted to determine if the degradation in performance when Soldiers fired through the HMD is attributable to resolution, limited FOV, image contrast, limited training and experience, or a disconnection between the aiming of the weapon system and the movement of the images in the HMD.

6. Weapon Compatibility Assessment

6.1 Objectives

The objective of the weapon compatibility assessment was to determine the ability of the Soldier to hold, aim, control, and operate various weapon systems while wearing the LW system including the BALCS and assault pack.

6.2 Apparatus

1. LW system, version 1.0
2. BALCS with detachable neck protector
3. Assault pack
4. Fighting load carrier (FLC)
5. M4 carbine with and without M203
6. M249 SAW
7. M68 reflex sight, also called CCO
8. DVS
9. M145 machine gun optic
10. MTWS

6.3 Procedures

6.3.1 Training

All Soldiers had previously qualified on all weapons used during this assessment.

6.3.2 Experimental Trials

Before beginning the assessment, Soldiers were given a brief explanation of the procedures. Six Soldiers were selected to participate in this assessment. Two Soldiers were configured as riflemen (with M4 carbine), two Soldiers as grenadiers (with M4 carbine and M203), and two Soldiers as M249 gunners (with M249 SAW). Soldiers in each of these configurations evaluated all four different LW clothing conditions. Soldiers wore the LW with the FLC; LW with FLC and BALCS body armor (including detachable neck protector); LW with FLC, BALCS, and assault pack; and LW with FLC and assault pack. Once configured, Soldiers assumed a standing, kneeling, and prone firing position using iron sights, M68 reflex sight, M145 machine gun optic, MTWS, or DVS. The Soldier then determined if he could properly hold the weapon,

aim the weapon, and operate the weapon and LW system. Evaluators noted comments made by the Soldiers and took photographs to document issues that were discovered.

6.4 Results

The raw comments collected in the weapon compatibility assessment are presented in appendix H. In the rifleman configuration, most of the Soldiers' comments were made when they wore the BALCS or used the MTWS. The issues noted with the MTWS were problems in opening the eyecup. Soldiers often had to place the spectacles against the eyecup several times before they could see the full FOV of the MTWS. Even in the standing firing position, Soldiers sometimes had to move the buttstock up on their shoulder to get the eyecup in the right position to open (see figure 21). Opening the MTWS eyecup was difficult when Soldiers were in the prone firing position and even more difficult when they were prone with the BALCS system. Generally, the BALCS interfered with the helmet, forcing the helmet and head downward (see figure 22). The addition of the assault pack further reduced head movement and added to the difficulty in getting a sight picture with iron sights, M68, or MTWS. When Soldiers wore the BALCS and assault pack in the prone firing position, using the DVS and viewing through the HMD was almost the only way to fire since the head was pushed down so far, the Soldier could not lift his head high enough to see the target (see figure 23). Soldiers had some difficulty getting the buttstock in the correct position when the assault pack or BALCS was worn.

Figure 21. Soldier raising buttstock to get MTWS eyecup in correct position to open.

Figure 22. BALCS pushes helmet and head forward.

Figure 23. BALCS and assault pack force head down and prohibit Soldier from aiming weapon at target.

For the grenadier configuration, most comments concerned the BALCS in the prone firing position, which did not allow the head to tilt back to obtain a view of the target. The MTWS eyecup was difficult to use in all conditions but much more difficult in the prone position with the BALCS. The problem with the BALCS was even worse when the assault pack was added. One Soldier stated that the DVS might be in the way slightly for loading the M203 round. Also, the zoom wheel for the DVS was not conveniently located and caused Soldiers to move their hands from the normal position on the forestock to operate it (see figure 24). Occasionally, the sling got in front of the DVS and obscured the view of the DVS (see figure 25). Soldiers also had some problems getting a good buttstock position when the BALCS or assault pack was added.

Figure 24. Zoom wheel in grenadier configuration is difficult to access in normal firing position.

For the SAW gunner configuration, there were many of the same comments as the other conditions. Again, the Soldiers had difficulty with the MTWS eye cup (see figure 26). Soldiers also had difficulty raising their heads to fire when they wore the BALCS or BALCS with assault pack. In the iron sight mode, the cable retainer clips for the MTWS were in the visual path (see figure 27). Soldiers had to remove the cable before they could fire with the iron sights. When using the DVS, Soldiers must take their left hands away from the normal firing position (holding buttstock) to operate the user interface device (UID) (see figure 28).

Figure 25. Sling obscuring view through DVS in grenadier configuration.

Figure 26. M249 gunner having difficulty opening MTWS eyecup.

Figure 27. For the M249, when Soldiers switched from the MTWS to iron sights, the retainer clips for the MTWS obstructed the view.

Figure 28. For the M249, Soldiers have to reach to pistol grip to access UID.

6.5 Discussion

Most of the compatibility issues of the LW system and the weapon systems were attributable to the interference of the BALCS and assault pack with the helmet and the difficulty opening the MTWS eyecup. In many cases in the prone firing position, the interference between the BALCS, assault pack, and the helmet prohibited the Soldier from sighting the weapon on the target. The eyecup on the MTWS was difficult to use in most firing positions. Soldiers often had to push the spectacles against the eyecup 3 or 4 times in order to get the full image. This problem was more pronounced in the prone firing position.

The buttstock positions of the weapons were also affected by the BALCS and the assault pack. As more straps and body armor cover the shoulder area, it becomes more difficult to find a place where the buttstock will seat properly. The buttstock tends to move out on the shoulder or higher on the shoulder with the addition of the body armor and straps.

In several cases, the LW controls required the subjects to move their hands from their normal weapon firing positions. For the M249, the UID is on the pistol grip on the forestock. Most M249 gunners put their hands on the buttstock of the weapon. In this case, they must move their hands to the front of the weapon to access the controls. For the grenadier, the zoom wheel is situated in a position that is a difficult to reach from a normal forestock hand position.

6.6 Recommendations

Body armor and helmet interference in the prone firing position has been a problem for several body armor systems. Research and design work to solve this problem without eliminating adequate ballistic protection is needed.

7. Mobility Evaluation

7.1 Objectives

The objectives of the mobility assessment were to determine if there are any gross mobility issues with the LW system and to identify human factors and safety issues with the system.

7.2 Apparatus

1. LW system version 1.0
2. BALCS with detachable neck protector
3. M4 carbine
4. M4 carbine with M203
5. M249 SAW

6. Mobility and portability course (known distance range)

7.3 Procedures

7.3.1 Training

Soldiers received training in the proper way to negotiate each obstacle. Soldiers walked the course and negotiated obstacles before they ran in the evaluation conditions.

7.3.2 Experimental Trials

Twelve Soldiers participated in this assessment. Four Soldiers were configured as riflemen, four Soldiers as grenadiers, and four Soldiers as M249 SAW gunners. In the first trial, Soldiers wore only their BDUs. In the second trial, Soldiers wore their BDUs and the LW System. In the third trial, Soldiers wore their BDUs, LW system, and the BALCS with plate inserts. The Soldiers were instructed to complete the obstacle course as fast as they safely could. Soldiers were given a 30-minute rest break between obstacle course runs.

7.4 Results

Mean completion time data are presented in appendix I. The total course time data were analyzed to determine if the different ensembles affected the Soldiers' ability to quickly negotiate the course. The mean overall time to negotiate the obstacle course was 416.7 seconds. The mean course completion time was 245.7 seconds for the BDU condition, 444.6 seconds for the BDU and LW condition, and 559.8 seconds for the BDU, LW, and BALCS condition. An ANOVA was performed on the total course time data. The results showed that there was a statistically significant difference in course completion time between the three conditions (F 1,11 = 129.1 p <.001). Figure 29 shows the mean course completion times for these conditions. Figure 30 shows the mean course completion times for the different ensembles for the rifleman, grenadier, and SAW gunner squad positions.

Notes were taken regarding any difficulties that Soldiers had in negotiating the course in LW equipment. The following is a list of issues that were reported by the Soldiers or noticed by the evaluators during these trials. Notes were not taken during the BDU-only condition. The notes for the LW condition are presented in table 3, and the notes for the LW condition with the BALCS are presented in table 4.

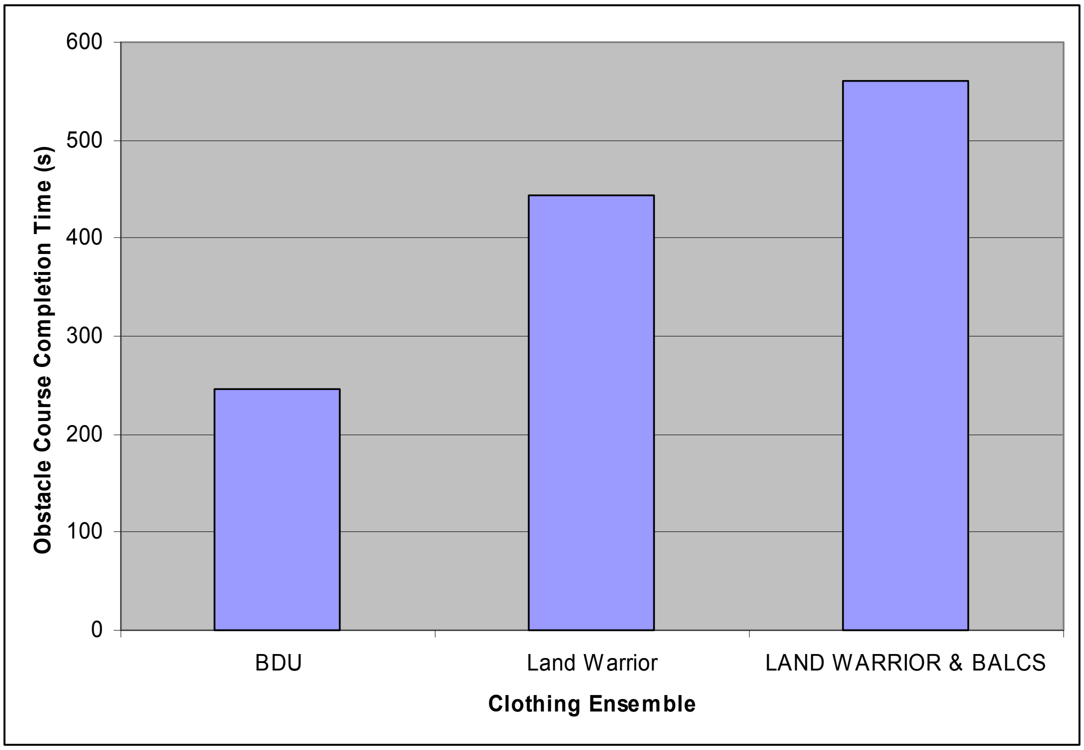

Figure 29. Mean obstacle course completion times for Soldiers wearing the BDU, LW, and LW with BALCS ensembles.

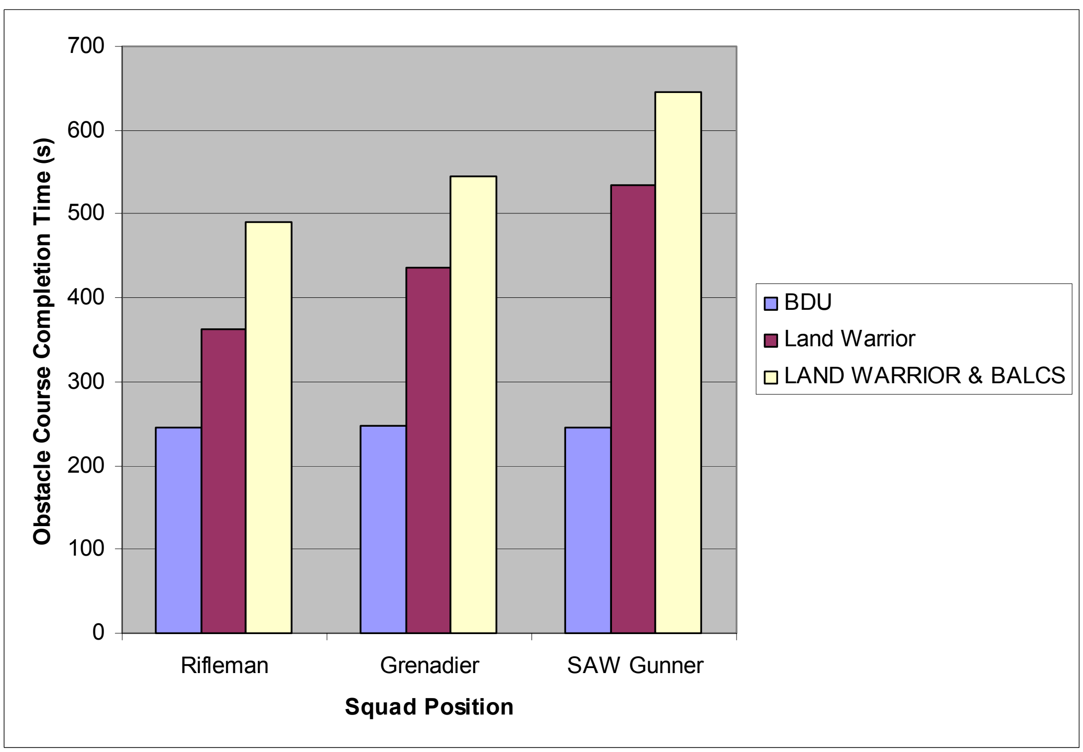

Figure 30. Mean obstacle course completion times for the rifleman, grenadier, and SAW gunner in BDU, LW, and LW with BALCS ensembles.

Table 3. Land warrior system.

TP1	Rifleman	Wire hung up on last obstacle. Soldier reported that cable to weapon shortened arm strides. Also felt that head movement was restricted.
TP2	SAW Gunner	Soldier reported that cables got hung up when slinging and unslinging M249
TP3	Grenadier	Soldier reported that helmet keeps hitting things because it is taller than he is used to. He said helmet is top heavy and sling is very restrictive.
TP4	SAW Gunner	Soldier reported that the system was heavy and the weapon cable got caught up in sling. SAW ammunition got caught on obstacle 13.
TP5	Rifleman	Soldier reported that the helmet wasn't tightened properly and it gave him problems.
TP6	SAW Gunner	Soldier reported no problems.
TP7	Rifleman	Lost DVS cap. Soldier reported he couldn't get weapon behind back enough to get over walls because of sling.
TP8	Grenadier	Ammunition pouch snagged on obstacles 13 and 16. Female portion of buckle on 40-mm round leg ammunition holder broke on wall (16)
TP9	Rifleman	Soldier reported that sling allowed weapon to hit him in the crotch. Helmet was too big and kept sliding down, reducing vision.
TP10	SAW Gunner	Soldier reported that weapon cord got tangled in his legs when going through windows. Soldier reported that sling was too short for weapon. Bipod legs kept coming out (low crawl and net).
TP11	Grenadier	Soldier reported that sling was bad. Soldier said it couldn't be adjusted correctly and takes too much time to adjust.
TP12	Grenadier	Soldier reported that the system was heavy, normal load-bearing equipment (LBE) much lighter. Said that sling was not good. The 40-mm leg ammunition holder slid around. SCU hung up on net.

Table 4. Land warrior system and BALCS with plates.

TP1	Rifleman	Soldier slipped on low window. Soldier tired.
TP2	SAW Gunner	Soldier reported difficulty getting over cargo net obstacle. Soldier said system was too bulky. Chin strap kept unbuckling.
TP3	Grenadier	Soldier reported that he hates all the wires. Weapon cable kept catching. Kept hitting top of helmet on things because it is higher than he expects. Getting over cargo net is difficult, SCU and upper 40-mm holder gets in way.
TP4	SAW Gunner	Weapon cable tangled in weapon. Soldier reported that sling is no good.
TP5	Rifleman	Soldier reported that getting over cargo net is difficult. BALCS has no flexibility. Hard to bend body to get over the top.
TP6	SAW Gunner	Soldier reported that sling caused problems and that he got his foot caught in weapon cable on the over-under obstacle.
TP7	Rifleman	Soldier reported that the system is bulky and it makes it difficult to get through obstacles. He said that it is hard to jump with all the weight. The bulk of the system forces you away from walls and makes it difficult to throw leg over.
TP8	Grenadier	Soldier reported that he couldn't be effective; too much stuff. Soldier said that SCU snags on top of net and the BALCS is not flexible.
TP9	Rifleman	Helmet quick release was snapped around sling. Soldier reported that the helmet was not properly sized.
TP10	SAW Gunner	Soldier reported that the BALCS was bulky. Computer and net boxes catch on things. Mouse joystick broke off.
TP11	Grenadier	Soldier reported sling problems; can't put weapon behind him.
TP12	Grenadier	Soldier reported that he had to unhook 40-mm holder leg strap to get over cargo net. Soldier reported that the SCU was catching on obstacles. Soldier thought SCU should not be in location where it will catch on things.

7.5 Discussion

As expected, as the load increased from BDU to LW to LW with BALCS, so did the time to negotiate the course. Also, the mean time to complete the course was shortest for the rifleman, slightly longer for the grenadier, and longest for the SAW gunner. This outcome was also expected because of the increased load that the grenadier and SAW gunner Soldiers are required to carry.

7.6 Recommendations

Several aspects of the system seemed to be problematic and need additional design work. The cable between the body and the weapon was prone to snagging and was generally disliked by the Soldiers. Possibly a lighter cable or wireless connection would be a better solution. The SCU mounted on the chest tended to snag on obstacles. A lower profile unit or moving the unit higher on the chest might reduce interference and breakage. The bulkiness of the BALCS system also caused many problems with mobility and slowed the Soldier. This is not uncommon for body armor systems. Research into flexible and lighter body armor could greatly increase the mobility of the dismounted Soldier.

8. Range of Motion Assessment

8.1 Objectives

The objective of this assessment was to examine Soldier ROM (with goniometric measurements from 15 different joint motions) when four equipment configurations were worn:

1. BDU (baseline),
2. BDU with LW rifleman LBE,
3. BDU with LBE and BALCS, and
4. BDU with LBE and JSLIST.

A complete description of the LBE, BALCS, and JSLIST is provided in appendix J.

8.2 Participants

All 12 Soldiers recruited from the 82nd Airborne Division, Fort Bragg, were used in this assessment.

8.3 Apparatus

1. Two 360-degree metal goniometers
2. LW LBE

3. BALCS body armor vests
4. JSLIST coats and trousers
5. SPEAR MICH with HMD
6. Soldiers' own BDUs
7. Soldiers' own M45 masks

8.4 Procedures

8.4.1 Goniometry

The available ROM at a specific joint can be determined through goniometric measures (Norkin and White, 1985). These measurements are obtained with a device known as a goniometer. A goniometer can be constructed from plastic or metal and typically consists of a protractor-like body, a stationary arm and a moving arm. A measuring scale, situated on the body of the goniometer, reads from 0 to 180 degrees or from 0 to 360 degrees, depending on the type of goniometer used. The type of goniometer used in this study is shown in figure 31.

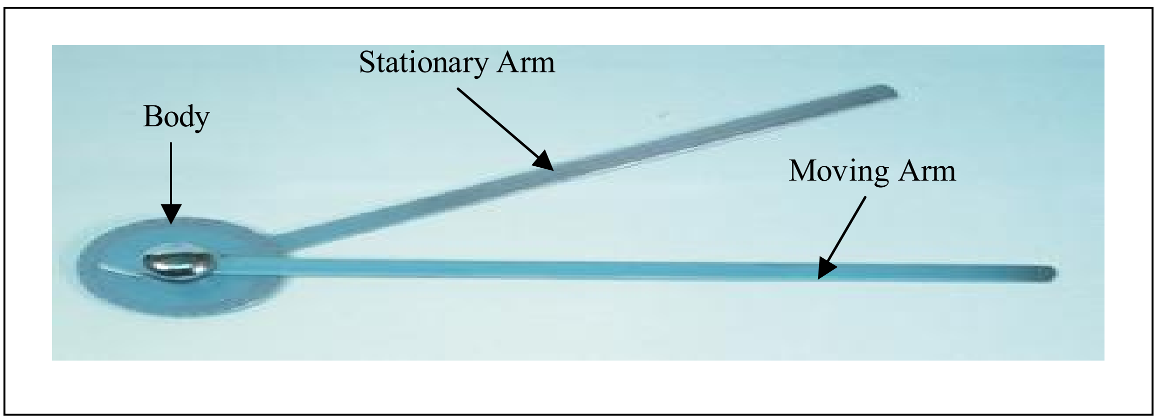

Figure 31. 360-degree stainless steel goniometer.

In goniometry, readings are first taken at the starting position (usually anatomic position or 0 degrees) and again at the ending position of joint motion in one of the three cardinal planes (sagittal, frontal, or transverse) about the three corresponding axes (transverse, anterior-posterior, and longitudinal). The planes of motion and axes of rotation are diagramed in figure 32. Motions are generally described in terms of the directions shown in figure 33. During goniometric measurements, the body of the goniometer is placed near the joint center, while the stationary and moving arms are generally aligned with the longitudinal axes of the proximal and distal portions of the joint, respectively. The corresponding joint position is then read from the scale on the body of the goniometer.

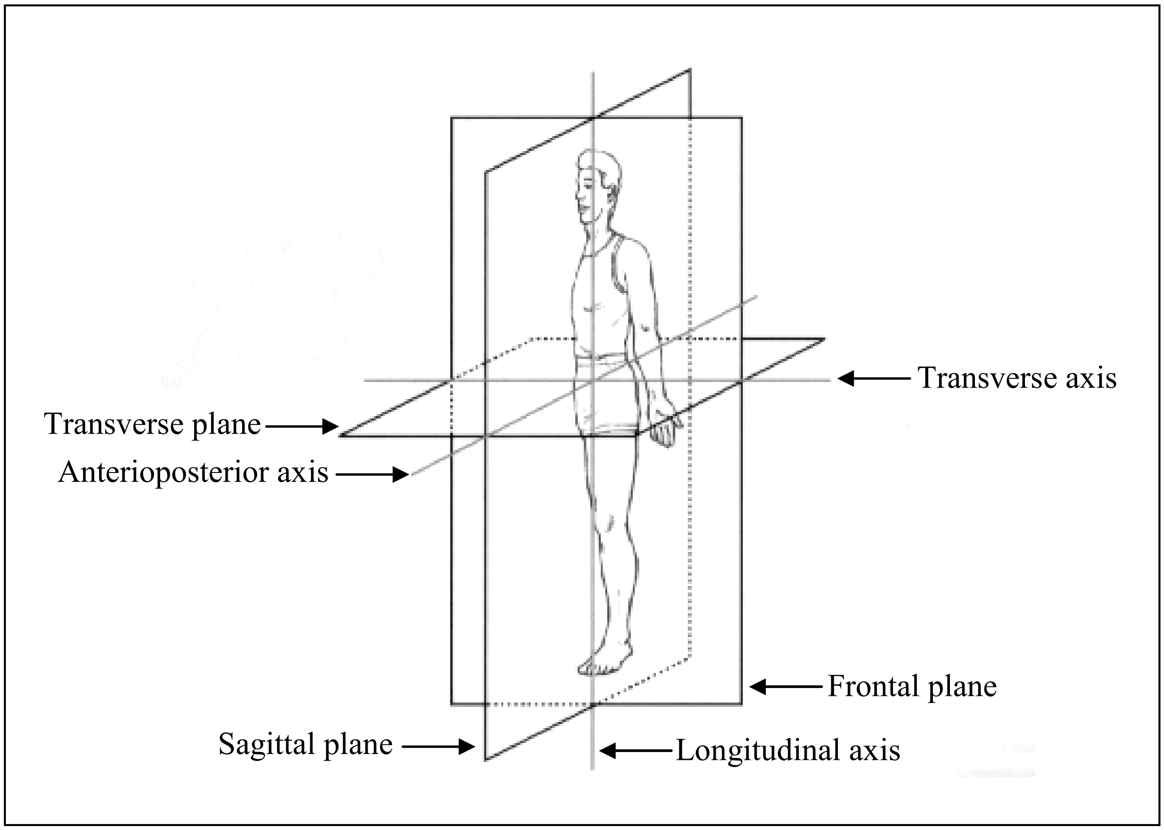

Figure 32. Planes of motion and axes of rotation.

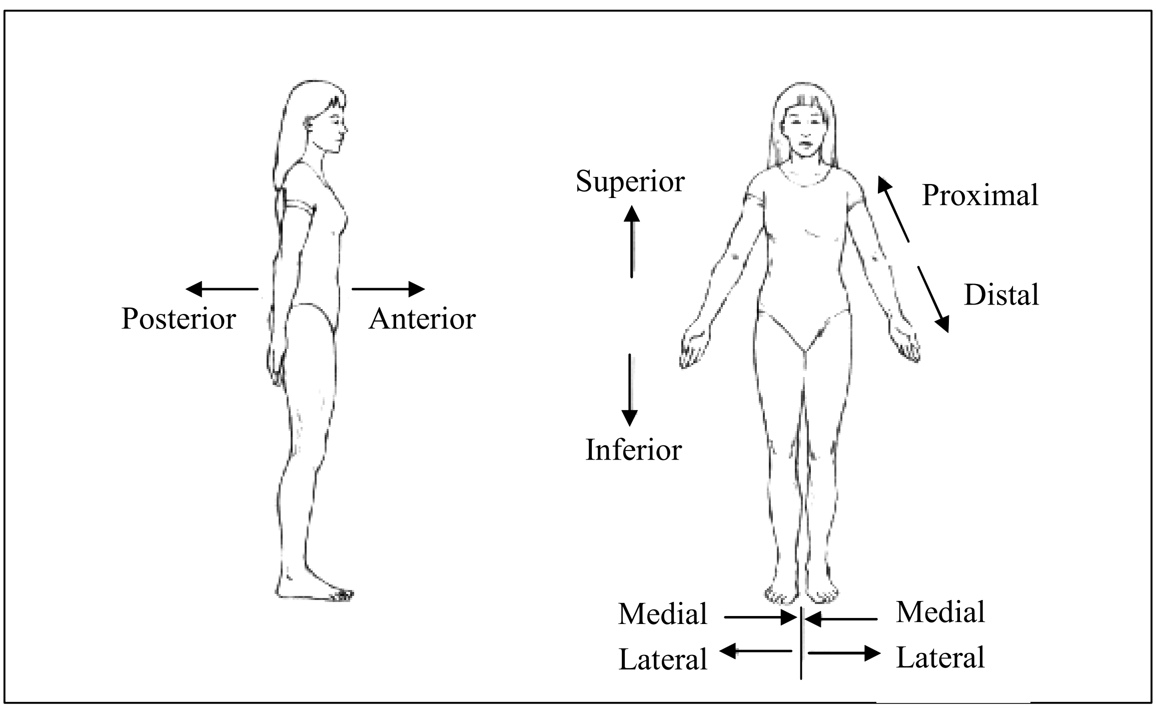

Figure 33. Directions of motion.

8.4.2 Assessment

The effects of four equipment configurations on total ROM were assessed for 15 joint motions. With the exception of head rotation and head lateral bending, all measurements were made on the right side of the body only. For each participant, three successive measurements of starting and ending position were recorded for each of the possible joint motion-equipment configuration combinations. Total ROM (end position minus start position) was then calculated for each of the three successive measurements of each possible joint motion-equipment configuration combination and averaged. In order to reduce inter-investigator error, the same investigator measured the same motions over all four equipment configurations. The measuring procedures used for each of the 13 joint motions are outlined in appendix K. Average ROM values given in appendix K are those reported by the American Academy of Orthopaedic Surgeons (1965).

Means and standard deviations for total ROM were calculated for each joint motion-equipment configuration combination. In order to identify statistically significant differences between the four equipment configurations, a univariate ANOVA was performed on the total ROM values calculated for each motion. For those motions found to be significantly affected by equipment configuration, a Tukey HSD *post hoc* test was additionally performed to identify differences between specific equipment configuration means. All statistical analyses were performed at a significance level of 0.05 with the Statistical Package for the Social Sciences (SPSS) 10.1 for Windows (SPSS, Inc., Chicago, IL).

8.5 Experimental Design

8.5.1 Independent Variables

The independent variables were the four equipment configurations: BDU only, BDU with LBE, BDU with LBE and BALCS, and BDU with LBE and JSLIST.

8.5.2 Dependent Variables

The dependent variables were total range of motion (in degrees) for head flexion, extension, rotation left, rotation right, lateral bending left and lateral bending right; shoulder flexion, extension, abduction and adduction; upper arm abduction; hip extension and flexion; and standing trunk flexion and extension (15 total dependent variables).

8.5.3 Evaluation Matrix

A within-subjects design was used so that each Soldier was exposed to each of the four equipment configurations. To reduce order effects, equipment configurations were presented to the Soldiers according to a counterbalancing scheme.

8.6 Results

Mean total ROM values and results of the statistical analyses are presented in table 5. A statistically significant effect of equipment configuration on Soldier ROM was identified for all

measured joint motions except standing trunk flexion and standing trunk extension. Total ROM under the BDU and LBE with JSLIST configuration was found to be significantly less than that under the BDU (baseline) configuration for all joint motions except head lateral bending to the right; significantly less than that under the BDU and LBE configuration for all joint motions except head flexion, shoulder adduction and hip extension; and significantly less than that under the BDU and LBE with BALCS configuration for hip extension and all of the head motions, with the exception of head lateral bending to the right. Under the BDU and LBE with BALCS configuration, total ROM was found to be significantly less than that under the BDU (baseline) configuration for left and right head rotation, all the upper body motions, and hip flexion and extension; significantly less than that under the BDU and LBE configuration for all the upper body motions and hip extension; and significantly less than that under the BDU and LBE with JSLIST configuration for shoulder adduction. Head rotation left, shoulder abduction and adduction, upper arm abduction, and hip flexion total ROM values under the BDU and LBE configuration were also found to be significantly less than under the BDU (baseline) configuration.

Table 5. Mean total ROM for 13 joint motions (in degrees).

Measurement	**Equipment Configuration**			
	BDU	**BDU and LBE**	**BDU and LBE with BALCS**	**BDU and LBE with JSLIST**
Head Flexion	59 (13)	51 (9)	55 (9)	43 (11) $^{\alpha\gamma}$
Head Extension	50 (10)	49 (8)	46 (11)	34 (7) $^{\alpha\beta\gamma}$
Head Rotation- Left	75 (13)	65 (9) $^{\alpha}$	62 (10) $^{\alpha}$	47 (12) $^{\alpha\beta\gamma}$
Head Rotation- Right	69 (10)	63 (8)	62 (7) $^{\alpha}$	46 (12) $^{\alpha\beta\gamma}$
Head Lateral Bending- Left	43 (8)	43 (6)	41 (6)	35 (5) $^{\alpha\beta\gamma}$
Head Lateral Bending- Right	40 (6)	43 (5)	41 (6)	36 (6) $^{\beta}$
Shoulder Flexion	148 (13)	140 (8)	121 (12) $^{\alpha\beta}$	121 (12) $^{\alpha\beta}$
Shoulder Extension	51 (10)	49 (6)	42 (7) $^{\alpha\beta}$	39 (4) $^{\alpha\beta}$
Shoulder Abduction	139 (17)	112 (13) $^{\alpha}$	88 (15) $^{\alpha\beta}$	89 (13) $^{\alpha\beta}$
Shoulder Adduction	51 (9)	40 (7) $^{\alpha}$	27 (9) $^{\alpha\beta\delta}$	36 (7) $^{\alpha}$
Upper Arm Abduction	143 (18)	115 (16) $^{\alpha}$	91 (15) $^{\alpha\beta}$	91 (17) $^{\alpha\beta}$
Hip Flexion	91 (10)	80 (13) $^{\alpha}$	79 (11) $^{\alpha}$	67 (10) $^{\alpha\beta\gamma}$
Hip Extension	40 (7)	38 (9)	32 (6) $^{\alpha\beta}$	33 (6) $^{\alpha}$
Standing Trunk Flexion	52 (17)	52 (12)	53 (12)	51 (11)
Standing Trunk Extension	33 (11)	32 (9)	28 (8)	27 (8)

Note: values given as mean (s.d.)
$^{\alpha}$ significantly less than BDU configuration mean (Tukey HSD, $p<0.05$)
$^{\beta}$ significantly less than BDU and LBE configuration mean (Tukey HSD, $p<0.05$)
$^{\gamma}$ significantly less than BDU and LBE with BALCS configuration mean (Tukey HSD, $p<0.05$)
$^{\delta}$ significantly less than BDU and LBE with JSLIST configuration mean (Tukey LSD, $p<0.05$)

8.7 Discussion

The objective of this study was to identify equipment effects on Soldier ROM. Of the 15 joint motions examined, 13 were significantly affected by equipment configuration. The BDU and LBE with JSLIST configuration appeared to place the most restrictions on Soldier ROM, with total ROM values for 13 of the joint motions being significantly lower than those of the BDU (baseline) configuration. Total ROM values for nine of the joint motions under the BDU and LBE with BALCS configuration were found to be significantly less than those of the (BDU) baseline configuration, making it the next most restrictive. With only five total ROM values being significantly lower than those of the BDU (baseline) configuration, BDU and LBE was the least restrictive configuration.

Under the BDU and LBE with JSLIST configuration, those total ROM values found to be significantly affected by equipment configuration were 18% to 37% less than corresponding values under the BDU (baseline) configuration. Head motions under the BDU and LBE with JSLIST configuration were observed to be primarily restricted by the hood of the JSLIST jacket, but the canister of the mask was found to interfere as well, contacting the subject's upper torso during head flexion. Reduction in total ROM for all the upper body motions, as well as hip flexion and extension, appeared to result from a lack of stretch in the garment's fabric. The bulkiness of the jacket fabric also contributed to the reduced total ROM for shoulder abduction and upper arm abduction, forcing the arm out and away from the body to a starting position value of approximately 25 degrees.

In comparison to total ROM values obtained under the BDU (baseline) configuration, significantly reduced values under the BDU and LBE with BALCS configuration were 17% to 47% less. Based on observation, reduction in total ROM values for the upper body motions can primarily be attributed to the bulkiness and lack of flexibility of the plates and vest that comprise the body armor. Shoulder abduction and upper arm abduction were also restricted by the shoulder straps of the LBE. Grenade and ammunition pouches on the front of the LBE also contributed to reduction in shoulder adduction total ROM. As with the BDU and LBE with JSLIST configuration, total ROM values for shoulder abduction and upper arm abduction were additionally reduced because of an increased starting position value (approximately 25 degrees). This increased starting position value was observed to result from the arm being forced out and away from the body by the bulkiness of the body armor and a general purpose pouch on the side of the LBE.

With respect to the total ROM values obtained under the BDU and LBE configuration, those found to be significantly affected by equipment configuration were 19% to 22% less than corresponding values obtained under the BDU (baseline) configuration. As with the BDU and LBE with BALCS configuration, shoulder abduction and upper arm abduction were observed to be restricted by the shoulder straps of the LBE, and shoulder adduction was observed to be restricted by the grenade and ammunition pouches. Shoulder abduction and upper arm abduction

total ROM were also reduced as a result of the general purpose pouch on the LBE forcing the arm out and away from the body, increasing the starting position value to around 21 degrees.

Based on the results of this study, it appears that Soldier equipment can significantly affect dismounted warrior ROM for head, upper body, and lower body motions. Of the three types of joint motions examined, upper body motions appear to be most affected by equipment configuration. This is notable in that many Soldier tasks require use of the upper extremities, and any restriction in ROM might lead to degradation in performance of those tasks. The degradation observed in head motion ROM could potentially result in reduced situational awareness with respect to the Soldier's immediate surroundings. Further investigation to better identify which aspects of Soldier equipment most significantly affect ROM is warranted. An attempt to define any existing relationship between reductions in ROM and degradation in Soldier performance should also be pursued.

8.8 Recommendations

1. Increased head ROM and freer shoulder movement might be achieved if the size of the hood were increased and the armholes on the JSLIST jacket were enlarged.
2. Less bulky materials capable of providing required chemical and biological protection while allowing more flexibility and increased ROM should be identified and evaluated for the construction of JSLIST garments.
3. Contact between the canister of the mask and the user's torso during head motions might be eliminated through modifications of the size, shape, and position of the canister on the mask.
4. ROM restrictions associated with the BALCS might be alleviated by the use of many smaller plates instead of a few large plates, especially in the shoulder area.
5. The inclusion of an elastic component in the shoulder straps of the LW LBE might mitigate restrictions of upper arm ROM.
6. Alternate locations for grenade, ammunition, and general purpose pouches on the LW LBE that would reduce interference with arm movements should be examined.

9. Future Work

The overall objective of this project was to identify human factors issues associated with the LW system (V 1.0). Several issues were identified and recommendations were made to alleviate the potential problems and increase overall system effectiveness. These recommendations or "lessons learned" should be applied to future warrior programs such as Objective Force Warrior,

which, like Land Warrior, is aimed at integrating technology with the Soldier. In addition, findings from this evaluation as well as other existing data should be compiled into a lessons learned database so that continuous improvements can be made and to avoid similar issues in the future.

10. References

American Academy of Orthopaedic Surgeons. *Joint Motion: Method of Measuring and Recording*. Chicago: American Academy of Orthopaedic Surgeons, 1965.

Clauser, C.; Tebbetts, I.O.; Bradtmiller, B.; McConville, J.T.; Gordon, C.C. *Measurer's Handbook: U.S. Army Anthropometric Survey 1987-1988*; TR-88-043; U.S. Army Natick RD&E Center: Natick, MA, 1988.

Garamone, J. *Army Tests Land Warrior for 21st Century Soldiers* (Vol. 2000), American Forces Press Service, 1998.

Gordon, C.C.; Bradtmiller, B.; Churchill, T.; Clauser, C.; McConville, J.T.; Tebbetts, I.O.; Walker, R.A. *Anthropometric Survey of U.S. Army Personnel: Methods and Summary Statistics*; Technical Report NATICK TR-89-044, AD A225 094; U.S. Army Natick RD&E Center: Natick, MA, 1989.

Miles, W.R. Ocular Dominance Demonstrated by Unconscious Sighting. *Journal of Experimental Psychology* **1929**, *12*, 113-126.

Norkin, C.C.; White, D.J. (Eds.). *Measurement of Joint Motion: A Guide to Goniometry*. F.A. Davis Company: Philadelphia, 1985.

Spencer, R.A. A*nalysis of Performance Resulting From the Design of Selected Hand-held Input Control Devices and Visual Displays*. Unpublished Master's Thesis. Virginia Polytechnic Institute and State University, Blacksburg, VA, 2000.

U.S. Department of the Army. DA Pam 611-21, 1999.

U.S. General Accounting Office. *Battlefield Automation* (Army's Restructured Land Warrior Program Needs More Oversight); GAO NSIAD-00-28; Washington, DC, December 1999.

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Appendix A. Volunteer Agreement Affidavit

VOLUNTEER AGREEMENT AFFIDAVIT:
ARL-HRED Local Adaptation of DA Form 5303-R. For use of this form, see AR 70-25 or AR 40-38

The proponent for this research is: U.S. Army Research Laboratory
Human Research and Engineering Directorate
Aberdeen Proving Ground, MD 21005

Authority:	Privacy Act of 1974, 10 USC 3013, 44 USC 3101, and 10 USC 1071-1087
Principal purpose:	To document voluntary participation in the Research program. Serial Number and home address will be used for identification and locating purposes.
Routine Uses:	The SSN and home address will be used for identification and locating purposes. Information derived from the project will be used for documentation, adjudication of claims, and mandatory reporting of medical conditions as required by law. Information may be furnished to Federal, State, and local agencies.
Disclosure:	The furnishing of your SSN and home address is mandatory and necessary to provide identification and to contact you if future information indicates that your health may be adversely affected. Failure to provide the information may preclude your voluntary participation in this data collection.

Part A • Volunteer agreement affidavit for subjects in approved Department of Army research projects
Note: Volunteers are authorized all necessary medical care for injury or disease that is the proximate result of their participation in such projects under the provisions of AR 40-38 and AR 70-25.

Title of Research Project:	ATC Safety Test, Weapon Compatibility and Shooting Assessment with Land Warrior Version 1.0	
Human Use Protocol Log Number:	ARL-20098-02009	
Principal Investigator(s):	Dave King, ATC	Phone: (410) 278-3018 dking@atc.army.mil
Associate Investigator(s)	Charles A. Hickey, Jr.	Phone: (410) 278-5994 charlieh@arl.army.mil
Location of Research:	ARL Mobility and Portability Research Facility ARL Small Arms Shooting Performance Facility	
Dates of Participation:	8 April – 31 May 2002	

I do hereby volunteer to participate in the research project described in the table above. I have full capacity to consent and have attained my 18th birthday. The implications of my voluntary participation, duration, and purpose of the research study, the methods and means by which it is to be conducted, and the inconveniences and hazards that may reasonably be expected have been explained to me. I have been given an opportunity to ask questions concerning this research project. Any such questions were answered to my full and complete satisfaction. Should any further questions arise concerning my rights or study related injury, I may contact the ARL-HRED Human Use Committee Chairperson at Aberdeen Proving Ground, Maryland, USA by telephone at 410-278-0612 or DSN 298-0612**. I understand that any published data will not reveal my identity. If I choose not to participate, or later wish to withdraw from any portion of it, I may do so without penalty. I understand that military personnel are not subject to punishment under the Uniform Code of Military Justice for choosing not to take part as human subjects and that no administrative sanctions can be given me for choosing not to participate. I may at any time during the course of the project revoke my consent and withdraw without penalty or loss of benefits. However, I may be required (military volunteer) or requested (civilian volunteer) to undergo certain examinations if, in the opinion of an attending physician, such examinations are necessary for my health and well being.**

Part B • To be completed by the Principal Investigator
Note: Instruction for elements of the informed consent provided as detailed explanation in accordance with Appendix C, AR 40-38 or AR 70-25.

Purpose

The purpose of this study is to conduct a safety test of the Land Warrior (LW) 1.0 Version by doing mobility, portability and shooting assessments of the LW in various configurations. The primary objectives are to identify any design characteristics or features that may impact mobility and portability; determine the user acceptance of the LW 1.0 for mobility and portability; determine the compatibility of the LW 1.0 with various weapon configurations; determine the ability of Soldiers to obtain a correct firing position and aim at targets on the range with the LW system and various weapon configurations and collect shooting assessment data with Soldiers wearing Land Warrior while firing the M4 carbine, M249, and M240B in various firing conditions and with various sights.

Procedures

You are being asked to participate in a safety test while doing mobility and shooting assessment of the Land Warrior (LW) 1.0 Version. The test includes mobility and portability maneuvers, live firing assessments, and compatibility while using the LW equipment in various configurations with various weapons and sighting devices. The tasks will include wearing the LW 1.0 in various configurations while carrying the weapon systems through a 4-km cross-country course and a 500-meter obstacle course. It also involves compatibility investigations with various LW configurations and weapons while in different firing positions. Live firing assessments with the LW configurations and weapons will be conducted during daylight and night time.

Training on the use, wearing, and operation of the LW 1.0 will be provided by a prime training contractor to insure that your are familiar with the system prior to your use and operation during the conduct of this test.

For the mobility and portability phase, you will be asked wear various LW configurations and carry a designated weapon system. You will carry total configuration weights up to 90 pounds. You will then be asked to negotiate the cross-country course twice and the obstacle course twice each day. Afterwards you will fill out questionnaires and participate in debriefing sessions.

For the compatibility phase, you will be asked to wear various LW configurations with a designated weapon and specific sighting system. You will then be asked to get into different firing positions. You will be asked if you have any difficulty or problems while aiming at designated targets downrange. You will then be asked to wear a different LW configuration with a designated weapon and the trials will be repeated.

For the daylight live firing assessment, you will be asked to wear various LW configurations with a designated weapon and specific sighting system. You will be provided training trials prior

to firing for record with the LW configuration, weapon and sighting system. You will be asked to engage targets at ranges from 50 to 300 meters with varying target exposure times. In addition, you will be asked to engage targets using the direct (through the lens) and indirect (through the Helmet Mounted Display) method of aiming and searching for targets. You will also be asked to conduct reduced exposure firing trials by firing to the left, right, and over a wall while using the Daylight Video Sight of the weapon system.

For the nighttime live firing assessment, you will be asked to wear various LW configurations with a designated weapon and specific night sight system. You will be provided training trials prior to firing for record with the LW configuration, weapon, and night sight system. You will be asked to engage targets at ranges from 50 to 300 meters with varying target exposure times. At the completion of the different tests, you may be asked to complete several questionnaires regarding your experience with the LW 1.0 and the tests you just completed.

During the conduct of this test, photographers may take pictures of you while conducting a particular task. If you do not wish to have your photograph taken, please inform the HRED personnel or ATC test director.

You may be asked to complete questionnaires about your prior experience.

This study will last about two weeks. Your work schedule will be Monday through Friday from approximately 0800 to 1600 hours for daylight operations. You may be asked to stay past 1600 hours to conduct night time operations possibly until 2200 hours on certain nights. The scheduled start date is April 8, 2002.

Demographic and anthropometric measurement data will be collected from you. Demographic data consists of your personal background and military experiences. Anthropometric data entails specific physical body dimensional measurements related to tasks and the items being investigated. You will also be tested for color blindness and visual acuity.

Thank you for your participation, and please feel free to ask the experimenter any questions you may have.

Benefits

Your participation in this study will help the Army assess the safety, mobility, portability, compatibility, and shooting capability of the Land Warrior 1.0 Version.

Risks

All risks encountered in this evaluation are minimal and typical of every day risks encountered by personnel working outdoors at the test areas where you will participate. Risks include physical fatigue, muscle strains, cuts, abrasions, broken bones, skin irritation, and injuries that may result from trips or falls. You are advised that there are wild animals, snakes, and poisonous insects in the vicinity of some of the test sites and to take the appropriate precautions. There is a risk of tick bites and the potential for Lyme disease at Aberdeen Proving Ground. You will be

encouraged to use insect repellent that will be available at the test site, and we will ask you to inspect yourself frequently for ticks.

Care will be taken to minimize risks using the following precautions. At all times and at all test sites, the wearers, observers and test personnel will be encouraged to drink water freely to prevent dehydration. The guidelines from TB Med 507 will be used to determine acceptable work rest schedules. Wet Bulb Globe Thermometer reading will be used in correspondence to work rest schedules. A copy of TB Med 507 will be kept available at all times. Daily meteorological records will be obtained from the Meteorological Service at Phillips Army Airfield. Also, the wet-bulb globe temperature (WBGT) and dry bulb temperature will be monitored at all test sites using portable WBGT monitors. While wearing body armor, if the heat index equals or exceeds 77 degrees F testing will be halted for the day. The WBGT limit for mobility and portability maneuvers will be 87 degrees F for seasoned Soldiers not wearing body armor.

Outdoor activities will be suspended during any weather conditions that are inherently dangerous or will cause evaluation trials to be dangerous. If it is raining or snowing, or if there is an accumulation of water or snow on the ground, outdoor test activities will be delayed or canceled, if conditions are believed to be unsafe. Water will be available and you will be instructed to drink often. Water breaks will occur at least every 30 minutes for all trials that exceed 30 minutes in duration. You will be given at least an hour-long break between the mobility-portability course trials. Mobility-portability course trials will be limited to two per day (2 cross country and 2 obstacle course runs). As applicable, air-conditioned or heated buildings will be available for breaks from the weather.

Hearing protection will be worn by all personnel during all small arms trials at M Range. Safety procedures are well established at M Range in SOP No. 385-H-188 and will be closely followed.

Confidentiality

All data and information obtained about you will be considered privileged and held in confidence. Photographic or video images of you taken during this data collection will not be identified with any of your personal information (name, rank, or status). Complete confidentiality cannot be promised, particularly if you are a military service member, because information bearing on your health may be required to be reported to appropriate medical or command authorities. In addition, applicable regulations note the possibility that the U.S. Army Medical Research and Materiel Command (MRMC-RCQ) officials may inspect the records.

Disposition of Volunteer Agreement Affidavit

The Principal Investigator will retain the original signed Volunteer Agreement Affidavit and forward a photocopy of it to the Chair of the Human Use Committee after the data collection. The test administrator will provide a copy to the volunteer

Contacts for Additional Assistance

If you have questions concerning your rights on experiment-related injury, or if you have any complaints about your treatment while participating in this experiment, you can contact:

Chair, Human Use Committee U.S. Army Research Laboratory Human Research and Engineering Directorate Aberdeen Proving Ground, MD 21005 (410) 278-0612 or (DSN) 298-0612	**OR**	Office of the Chief Counsel U.S. Army Research Laboratory 2800 Powder Mill Road Adelphi, MD 20783-1197 (301) 394-1070 or (DSN) 290-1070

Your signature below indicates that you: (1) are at least 18 years of age, (2) have read the information on this form, (3) have been given the opportunity to ask questions and they have been answered to your satisfaction, and (4) have decided to participate based on the information provided on this form.

Printed Name of Volunteer (First, MI., Last)	
Social Security Number (SSN)r	***Permanent Address of Volunteer***
Date of Birth *(Month, Day, Year)*	
Today's Date *(Month, Day, Year)*	***Signature of Volunteer***
Signature of Administrator	

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Appendix B. Demographic and Anthropometric Data

Table B-1. Demographic data.

Test Participant Identification Number	**1**	**2**	**3**	**4**	**5**	**6**
MOS	11B3PG	11B	11B1P	11B1P	11B1P	11B1P
Rank	E-6	E-6	E-5	E-4	E-4	E-4
Duty Position Title	Assistant Operations	Squad Leader	Team Leader	SAW Gunner	Rifleman	Rifleman
Time in Service	17 yr, 6 mo	5 yr, 1 mo	4 yr, 6 mo	3.yr, 4 mo	2 yr, 6 mo	2 yr, 3 mo
Time at present Duty Station	3 yr, 10 mo	1 yr, 10 mo	3 yr, 5 mo	6 mo	2 yr	1 yr, 9 mo
DOB	05-Oct-65	12-Aug-75	01-Nov-73	23-Sep-75	03-Dec-80	04-Jan-80
Age, yr	36	26	28	26	21	22
Place of Birth	Richmond, VA	Seoul, South Korea	Eau Claire, WI	Billings, MT	Los Angeles, CA	Vancouver, WA
Weapons qualified		M4, M249, M240	M4, M249, M240, AT4	M249	M4	
Qualification badges		EIB	EIB		EIB	
Land navigation skill rating:						
Identify topographic symbols on a military map	10	10	10	8	10	8
Identify terrain features on a military map	10	10	10	8	10	10
Determine grid coordinates on a military map	10	10	10	9	10	10
Determine an azimuth using a lensatic compass	10	10	10	9	10	10
Determine your location using terrain association	10	10	10	8	9	9
Measure distance on a map	10	10	10	8	10	10
Orient a map using map to terrain association	10	10	10	9	10	9
Determine direction without a compass	10	10	10	8	8	7
Communication skill rating:						
Use of Pro-words	10	10	10	9	10	7

Table B-1 (continued)

Test Participant Identification Number	**1**	**2**	**3**	**4**	**5**	**6**
Knowledge of phonetic alphabet	10	10	10	10	10	10
Use of alphanumeric pronunciation	10	10	10	10	10	10
Physical injuries	None	None	None	None	None	None
Handedness	right	right	right	right	right	right
Corrective lenses	No	No	No	No	Yes	No
Contacts	No	No	No	No	Yes	No
Computer training and experience:						
IBM	Yes	No	No	Yes	No	Yes
Macintosh	No	No	No	Yes	No	No
Software used:						
Microsoft Word	Yes	No	No	No	No	Yes
Word Perfect	Yes	No	No	No	No	Yes
Microsoft Windows	Yes	Yes	No	Yes	Yes	Yes
Microsoft Office	Yes	No	No	No	No	Yes
Multimate	Yes	No	No	No	No	No
MacWrite	No	No	No	Yes	No	No
Computer skill rating	9	1	5	5	8	9
Highest level of education	Some College	Some College	Some College	Some College	HS Grad, GED	HS Grad, GED
Swimming skill rating	9	10	10	10	10	8

Table B-1 (continued)

Test Participant Identification Number	**7**	**8**	**9**	**10**	**11**	**12**
MOS	11B1P	11B2P2C	11B1P	11B1P	11B1P	11B1P
Rank	E-3	E-5	E-4	E-4	E-4	E-3
Duty Position Title	SAW Gunner	Team Leader	Javelin Gunner	Rifleman	Saw Gunner	Saw Gunner
Time in Service	1 yr, 0 mo	6 yr, 1 mo	2 yr, 1 mo	2 yr, 9 mo	2 yr, 4 mo	1 yr, 0 mo
Time at present Duty Station	0 yr, 8 mo	2 yr, 1 mo	1 yr, 7 mo	2 yr, 5 mo	1 yr, 11 mo	0 yr, 7 mo
DOB	30-Aug-73	07-Oct-71	29-Apr-79	23-Mar-81	29-Dec-80	17-Jul-81
Age, yr	28	30	23	21	21	21
Place of Birth	Marietta, GA	Los Angeles, CA	Washington D.C.	Ft. Worth, TX	Lubbock, TX	Huntington, NY
Weapons qualified	M4, M249	M4, M203, Javelin	M4, Javelin	M4, M249	M249	M4, M249
Qualification badges		Airborne	Airborne	EIB, Airborne	Airborne	Airborne
Land navigation skill rating:						
Identify topographic symbols on a military map	10	10	9	8	8	8
Identify terrain features on a military map	9	7	10	8	9	8
Determine grid coordinates on a military map	10	10	10	8	10	8
Determine an azimuth using a lensatic compass	10	10	10	8	10	6
Determine your location using terrain association	10	8	10	8	8	7
Measure distance on a map	10	10	10	8	9	8
Orient a map using map to terrain association	10	9	10	8	8	8
Determine direction without a compass	9	7	9	8	6	7
Communication skill rating:						
Use of Pro-words	8	8	10	10	8	7
Knowledge of phonetic alphabet	10	9	10	10	9	10
Use of alphanumeric pronunciation	10	9	10	10	10	10
Physical injuries	None	None	None	None	None	None
Handedness	Right	Right	Right	Right	Right	Right
Corrective lenses	Yes	No	Yes	No	Yes	No
Contacts	Yes	No	No	No	No	No
Computer training and experience:						
IBM	No	Yes	Yes	Yes	No	No
Macintosh	No	Yes	Yes	No	No	No
Software used:						

Table B-1 (continued)

Test Participant Identification Number	**7**	**8**	**9**	**10**	**11**	**12**
Microsoft Word	Yes	Yes	Yes	Yes	Yes	No
Word Perfect	Yes	Yes	Yes	No	No	No
Microsoft Windows	Yes	Yes	Yes	Yes	Yes	No
Microsoft Office	Yes	Yes	Yes	No	No	No
Multimate	No	No	No	No	No	No
MacWrite	No	Yes	Yes	No	No	No
Computer skill rating	10	10	9	8	9	9
Highest level of education	Some College	Associates Degree	HS Grad, GED	HS Grad, GED	HS Grad, GED	Some College
Swimming skill rating	10	7	6	10	8	10

Table B-2. Land Warrior Version 1.0 Safety Test - Anthropometric Measurements of Individual Soldiers.

Soldier ID No.	Weight		Stature		Cervicale Height		Acromial Height		Crotch Height		Chest Breadth		Chest Depth		Neck Circum-ference		Shoulder Circum-ference	
	kg	%	cm	%	cm	%	cm	%	cm	%	cm	%	cm	%	cm	%	cm	%
1	112.6	99	186.1	94	162.1	94	151.0	86	88.9	86	36.1	92	30.0	99	44.2	99	134.4	99
2	80.7	61	174.3	43	148.6	30	143.0	43	85.6	67	29.7	17	25.4	70	38.0	53	120.1	67
3	85.4	75	178.0	64	149.4	35	143.3	44	85.7	68	32.4	57	32.4	57	39.4	77	123.3	83
4	86.5	78	190.3	99	165.1	98	157.3	98	97.0	99	32.7	61	27.7	93	36.5	23	116.5	44
5	86.2	77	177.4	61	154.1	64	147.6	71	84.4	58	34.6	83	27.4	91	39.1	73	128.4	96
6	72.8	32	171.3	27	148.5	30	141.4	33	86.4	73	29.6	16	23.9	44	38.2	57	113.0	23
7	81.3	63	172.4	32	149.4	35	140.8	29	82.4	40	32.1	53	25.0	64	38.3	59	120.2	68
8	73.4	34	172.0	30	149.0	33	141.4	33	80.4	24	31.6	45	22.3	18	37.5	42	113.0	23
9	66.6	14	176.5	56	151.0	45	142.1	37	82.5	41	27.5	2	23.9	44	36.0	16	105.5	2
10	77.4	49	178.7	68	155.6	72	147.3	69	85.0	62	30.7	31	25.3	69	40.0	85	121.8	77
11	73.4	34	171.3	27	148.7	31	139.7	23	81.6	34	29.7	17	23.2	31	36.4	21	118.4	56
12	77.9	51	171.4	27	146.9	21	138.5	18	84.0	54	34.1	79	26.0	78	40.0	85	123.8	85
mean	81.2		176.6		152.4		144.5		85.3		31.7		26.0		38.6		119.9	
sd	11.6		6.1		5.8		5.4		4.3		2.5		2.9		2.2		7.6	
min	66.6	14	171.3	27	146.9	21	138.5	18	80.4	24	27.5	2	22.3	18	36.0	16	105.5	2
max	112.6	99	190.3	99	165.1	98	157.3	98	97.0	99	36.1	92	32.4	99	44.2	99	134.4	99

Table B-2 (continued)

SOLDIER ID No.	Chest Circum-ference		Waist Circum-ference		Waist Front Length (O)		Waist Back Length (O)		Sitting Height		Eye Height Sitting		Acromial Height Sitting		Biacromial Breadth		Bideltoid Breadth	
	cm	%	cm	%	cm	%	cm	%	cm	%	cm	%	cm	%	cm	%	cm	%
1	114.6	98	105.8	98	44.4	88	49.0	68	94.1	77	82.4	82	57.9	26	47.7	99	55.3	99
2	97.1	38	84.5	45	40.7	39	49.0	68	92.7	64	80.6	65	59.1	41	42.7	95	50.4	68
3	99.1	52	87.2	57	42.2	64	45.2	16	94.1	77	82.2	81	59.8	50	43.8	99	50.3	67
4	102.2	69	96.2	86	40.0	28	47.5	45	92.9	66	79.4	52	60.3	57	40.7	71	48.1	35
5	107.0	87	94.6	83	42.4	67	48.5	61	93.1	68	80.4	63	63.0	86	41.9	89	52.4	89
6	94.7	27	82.5	36	39.0	15	46.4	29	87.6	15	76.1	19	56.7	15	38.4	24	46.1	12
7	98.0	46	88.0	60	40.3	33	48.3	58	91.3	49	80.0	59	59.5	46	42.3	92	51.0	76
8	94.0	24	89.1	65	40.4	34	48.0	53	94.6	81	83.5	89	64.2	93	39.1	37	46.9	19
9	87.3	3	77.0	14	39.8	25	47.0	38	93.1	68	80.9	69	56.7	15	39.3	41	44.2	2
10	97.2	38	81.3	31	41.1	46	49.5	74	94.3	79	83.0	86	61.4	71	41.8	88	49.4	54
11	92.4	16	83.7	42	39.2	18	48.1	55	90.8	43	79.0	47	59.1	41	40.5	67	49.1	49
12	102.0	68	87.7	59	35.8	1	43.6	5	88.2	19	76.7	23	56.5	13	40.6	69	49.0	48
mean	98.8		88.1		40.4		47.5		92.2		80.4		59.5		41.6		49.4	
sd	7.1		7.7		2.1		1.7		2.3		2.3		2.5		2.5		2.9	
min	87.3	3	77.0	14	35.8	1	43.6	5	87.6	15	76.1	19	56.5	13	38.4	24	44.2	2
max	114.6	98	105.8	98	44.4	88	49.5	74	94.6	81	83.5	89	64.2	93	47.7	99	55.3	99

Table B-2 (continued)

SOLDIER ID No.	Abdominal Ext. Depth		Bitragion Chin Arc		Bitragion Coronal Arc		Bitragion Crinion Arc		Bitragion Frontal Arc		Bitragion Submand. Arc		Bitragion Subnasale Arc		Head Circum-ference		Hand Circum-ference	
	cm	%	cm	%	cm	%	cm	%	cm	%	cm	%	cm	%	cm	%	cm	%
1	31.3	99	36.6	99	35.5	55	32.5	46	31.1	74	35.0	99	32.0	99	58.8	91	22.3	83
2	21.5	21	35.5	98	35.6	98	33.0	63	31.5	84	31.6	79	32.2	99	57.0	57	21.9	71
3	23.4	47	34.9	95	36.6	84	32.1	33	30.6	57	34.0	99	31.0	94	60.4	99	21.8	68
4	26.2	80	32.3	42	37.0	90	33.7	82	32.0	92	31.1	69	30.0	77	59.3	95	21.5	57
5	26.0	78	33.3	71	35.5	55	33.0	63	31.3	79	30.6	56	30.5	88	56.5	43	22.2	80
6	22.5	34	32.2	39	35.8	65	32.2	36	31.1	74	30.2	45	30.4	86	55.5	21	21.6	60
7	24.9	67	32.7	54	34.7	31	32.5	46	31.0	71	30.0	39	29.5	61	56.0	31	21.4	52
8	22.9	40	32.9	60	35.6	58	32.2	36	31.0	71	31.4	76	30.0	77	54.9	11	21.1	40
9	19.8	5	30.5	6	34.6	28	31.0	8	29.8	28	29.0	16	27.8	10	56.2	36	20.9	32
10	21.6	22	34.3	90	35.4	52	32.2	36	30.5	53	32.5	92	30.0	77	56.8	51	21.0	36
11	23.4	47	32.0	33	34.3	21	30.5	3	29.1	11	30.0	39	28.5	27	55.2	15	20.5	18
12	23.5	49	32.7	54	35.5	55	31.3	13	29.2	13	31.0	66	28.9	40	55.7	24	22.3	83
mean	23.9		33.3		35.5		32.2		30.7		31.4		30.1		56.9		21.5	
sd	3.0		1.7		0.8		0.9		0.9		1.7		1.3		1.7		0.6	
min	19.8	5	30.5	6	34.3	21	30.5	3	29.1	11	29.0	16	27.8	10	54.9	11	20.5	18
max	31.3	99	36.6	99	37.0	98	33.7	82	32.0	92	35.0	99	32.2	99	60.4	99	22.3	83

Table B-2 (continued)

SOLDIER ID No.	Head Breadth		Head Length		Menton-Sellion Length		Ear Breadth		Hand Breadth		Hand Length		Interpupillary Breadth	
	cm	%	cm	%	cm	%	cm	%	cm	%	cm	%	cm	%
1	16.1	95	19.6	43	13.1	91	4.1	89	9.1	83	21.1	95	7.2	97
2	15.0	38	20.1	71	11.8	28	3.8	55	8.9	38	20.2	81	6.3	29
3	15.9	91	21.1	98	12.0	39	4.1	89	9.0	47	19.5	57	5.8	2
4	15.0	38	21.0	97	11.6	18	3.2	2	9.0	47	20.7	91	6.6	60
5	15.1	46	19.5	38	12.8	82	3.7	40	9.0	47	21.4	97	6.9	87
6	15.1	46	19.5	38	11.9	34	3.4	8	8.9	38	19.4	53	6.2	20
7	15.0	38	19.4	32	12.1	46	3.5	16	8.6	15	19.1	40	6.4	44
8	15.4	68	18.5	5	12.5	69	3.4	8	8.7	21	18.5	18	6.3	29
9	15.4	68	19.3	27	11.0	3	3.4	8	8.6	15	19.3	49	6.0	8
10	15.6	80	19.4	32	12.3	58	3.4	8	8.4	6	19.7	65	6.7	70
11	15.1	46	18.8	10	10.8	1	3.4	8	8.4	6	19.5	57	6.1	16
12	14.8	24	19.6	43	11.4	11	3.6	26	9.1	56	19.0	36	6.2	20
mean	15.3		19.7		11.9		3.6		8.8		19.8		6.4	
sd	0.4		0.8		0.7		0.3		0.3		0.9		0.4	
min	14.8	24	18.5	5	10.8	1	3.2	2	8.4	6	18.5	18	5.8	2
max	16.1	95	21.1	98	13.1	91	4.1	89	9.1	83	21.4	97	7.2	97

Appendix C. Vision Screening Data

Table C-1. Summary of Soldier Vision Examinations.

Soldier ID No.	Far Visual Acuity[1]			Near Visual Acuity[1]			Stereo[2] Depth Perception	Color Vision	Ocular Dominance	Glasses or Contacts Worn
	Both Eyes	Right Eye	Left Eye	Both Eyes	Right Eye	Left Eye				
1	20/15	20/25	20/18	14/13	14/16	14/18	20/95	Normal	Left Eye	No
2	20/25	20/30	20/25	14/14	14/13	14/20	100/50	Mild Def.	Right Eye	No
3	20/17	20/20	20/18	14/13	14/16	14/12	50/70	Normal	Right Eye	No
4	20/30	20/35	20/30	14/11	14/14	14/11	20/95	Normal	Right Eye	No
5	20/35	20/40	20/30	14/14	14/18	14/20	20/95	Normal	Right Eye	Contacts[3]
6	20/13	20/17	20/15	14/11	14/13	14/11	20/95	Normal	Right Eye	No
7	20/18	20/18	20/18	14/12	14/13	14/13	25/90	Normal	Right Eye	Glasses[4]
8	20/15	20/15	20/18	14/12	14/10	14/13	20/95	Normal	Right Eye	No
9	20/15	20/17	20/15	14/10	14/12	14/10	20/95	Normal	Right Eye	Glasses[4]
10	20/13	20/18	20/15	14/10	14/11	14/10	20/95	Normal	Right Eye	No
11	20/25	20/70	20/30	14/13	14/13	14/13	200/30	Mild Def.	Right Eye	Glasses[5]
12	20/18	20/15	20/17	14/10	14/10	14/11	25/90	Normal	Right Eye	No

[1]20’ (Far) and 14” (Near) Visual Acuity presented as Snellen Fractions.
[2]Numbers represent angle of stereopsis in seconds of arc, Shepard-Fry Percentages.
[3]Soldier wearing contacts during vision examination.
[4]Soldier wearing glasses during vision examination.
[5]Soldier not wearing glasses during vision examination because he did not have them.

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Appendix D. Input Device Questionnaire

Table D-1. Post-test questionnaire.

Subject Number ______ Task Number ________________

Trial Number ________ Glove Type _________________

Please circle the answer that best represents your response to each statement

Question	Response				
1. Entering text and numbers was:	Easy X	X	Neither Easy Nor Hard X	X	Difficult X
2. Physical effort required to perform the task was:	Too Low X	X	Just Right X	X	Too High X
3. Finger and Wrist fatigue:	None X	X	Medium X	X	Very High X
4. Finger and Wrist Pain:	None X	X	Medium X	X	Very High X
5. General comfort:	Very Comfortable X	X	Comfortable X	X	Very Uncomfortable X
6. Overall, the input device was:	Very Easy to Use X	X	Neither Easy Nor Difficult to Use X	X	Very Difficult to Use X

Additional comments:

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Appendix E. Glove Compatibility Time Data

	Time	
Glove	Mean	SD
Bare Hand	156.91	34.28
25 mil Butyl Rubber	156.88	33.62
Trigger Finger	282.15	101.42
Leather Utility	165.37	18.50
Bare Hand (Dark Room)	131.65	17.48
Butyl Rubber Glove + M45 Mask	152.04	22.82
Bare Hand + M45 Mask	153.53	16.76

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Appendix F. Questionnaire Data

Question	Bare Hand		NBC		Trigger Finger		Utility	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	1.71	1.25	1.86	1.46	4.25	1.16	2.57	0.98
2	3.00	0.82	2.57	1.13	3.75	1.39	2.57	1.13
3	1.86	0.90	2.43	0.98	3.75	1.39	2.14	0.90
4	1.71	0.95	2.00	1.15	3.38	1.41	1.86	0.90
5	3.14	1.07	3.29	0.95	2.75	1.49	2.86	0.69
6	2.00	1.00	2.29	0.95	4.25	0.71	2.71	0.76

Question	Bare Hand (Dark Room)		Bare Hand & Mask		NBC Glove and Mask	
	Mean	SD	Mean	SD	Mean	SD
1	1.86	1.21	1.30	0.60	2.0	1.0
2	2.57	0.79	3.0	1.0	1.70	0.60
3	2.0	1.0	2.0	1.0	2.0	1.0
4	2.0	1.0	2.0	1.0	2.0	1.0
5	3.0	0.58	3.3	1.5	3.3	1.2
6	2.14	0.90	3.3	0.6	3.0	1.0

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Appendix G. Shooting Performance Means

G-1. M4 Daylight Firing

Means

% Hits * Sight

% Hits

Sight	Mean	N	Std. Deviation
CCO	.59	864	.491
DVS	.40	864	.490
Total	.50	1728	.500

% Hits * Firing Position

% Hits

Firing Position	Mean	N	Std. Deviation
Stand	.39	432	.489
Kneel	.46	432	.499
Foxhole	.59	432	.493
Prone	.54	432	.499
Total	.50	1728	.500

% Hits * EXPOSURE

% Hits

EXPOSURE	Mean	N	Std. Deviation
3	.31	576	.461
5	.51	576	.500
8	.67	576	.471
Total	.50	1728	.500

% Hits * RANGE

% Hits

RANGE	Mean	N	Std. Deviation
50	.83	288	.376
100	.66	288	.473
150	.59	288	.493
200	.36	288	.482
250	.30	288	.458
300	.23	288	.421
Total	.50	1728	.500

Report

% Hits

Sight	EXPOSURE	Mean	N	Std. Deviation
CCO	3	.46	288	.499
	5	.57	288	.496
	8	.75	288	.434
	Total	.59	864	.491
DVS	3	.15	288	.357
	5	.45	288	.499
	8	.59	288	.493
	Total	.40	864	.490
Total	3	.31	576	.461
	5	.51	576	.500
	8	.67	576	.471
	Total	.50	1728	.500

Report

% Hits

Sight	RANGE	Mean	N	Std. Deviation
CCO	50	.92	144	.277
	100	.77	144	.422
	150	.71	144	.456
	200	.40	144	.492
	250	.42	144	.496
	300	.34	144	.475
	Total	.59	864	.491
DVS	50	.74	144	.438
	100	.56	144	.499
	150	.47	144	.501
	200	.33	144	.471
	250	.17	144	.380
	300	.12	144	.324
	Total	.40	864	.490
Total	50	.83	288	.376
	100	.66	288	.473
	150	.59	288	.493
	200	.36	288	.482
	250	.30	288	.458
	300	.23	288	.421
	Total	.50	1728	.500

Report

% Hits

Sight	Firing Position	Mean	N	Std. Deviation
CCO	Stand	.44	216	.498
	Kneel	.57	216	.496
	Foxhole	.68	216	.469
	Prone	.69	216	.464
	Total	.59	864	.491
DVS	Stand	.34	216	.476
	Kneel	.35	216	.479
	Foxhole	.50	216	.501
	Prone	.40	216	.491
	Total	.40	864	.490
Total	Stand	.39	432	.489
	Kneel	.46	432	.499
	Foxhole	.59	432	.493
	Prone	.54	432	.499
	Total	.50	1728	.500

Repor t

%

Sigh	EXPOSUR	RANG	Mea n	N	Std. Deviation
CC O	3	5	.7	4	.41
		10	.7	4	.42
		15	.6	4	.49
		20	.2	4	.42
		25	.2	4	.44
		30	.1	4	.30
		Tota	.4	28	.49
	5	5	.9	4	.14
		10	.6	4	.49
		15	.7	4	.42
		20	.3	4	.46
		25	.4	4	.50
		30	.3	4	.46
		Tota	.5	28	.49
	8	5	.9	4	.14
		10	.9	4	.24
		15	.7	4	.43
		20	.6	4	.47
		25	.5	4	.50
		30	.6	4	.49
		Tota	.7	28	.43
	Tota l	5	.9	14	.27
		10	.7	14 4	.14
		15	.0	4	.14
		20	.1	28	.35
		25	.9	4	.20
		30	.6	4	.49
		Tota	.5	4	.50
DV S	3	5	.3	4	.48
		10	.2	4	.41
		15	.0	4	.27
		20	.4	28	.49
		25	.9	4	.20
		30	.7	4	.41
		Tota	.6	4	.47
	5	5	.5	4	.50
		10	.2	4	.45
		15	.2	4	.43
		20	.5	28	.49
		25	.7	14	.43
		30	.5	14	.49
		Tota	.4	14	.50
	8	5	.3	14	.47
		10	.1	14	.38
		15	.1	14	.32
		20	.4	86	.49
		25	.5	9	.50
		30	.5	9	.50
		Tota	.4	9	.49
	Tota l	5	.1	9	.34
		10	.1	9	.35
		15	.0	9	.24
		20	.3	57	.46
		25	.9	9	.17
		30	.6	9	.49
		Tota	.6	9	
Tota l	3	5	4	0	
		10			
		15			
		20			
		25			
		30			
		Tota			
	5	5			
		10			
		15			.48
		20	.3	9	.47
		25	.3	9	.47
		30	.2	9	.40
		Tota	.5	57	.50
	8	5	.9	9	.17
		10	.8	9	.34
		15	.7	9	.45
		20	.6	9	.48
		25	.4	9	.49
		30	.4	9	.49
		Tota	.6	57	.47
	Tota l	5	.8	28	.37
		10	.6	28	.47
		15	.5	28	.49
		20	.3	28	.48
		25	.3	28	.45
		30	.2	28	.42
		Tota	.5	172	.50

G-2 M4 Reduced Exposure Firing

Means

Report

% Hits

FIRPOS	WEAPPOS	Mean	N	Std. Deviation
Stand	Over	.36	144	.482
	Left	.39	162	.489
	Right	.40	144	.492
	Total	.38	450	.487
Kneel	Over	.32	144	.468
	Left	.33	126	.470
	Right	.37	144	.484
	Total	.34	414	.474
Total	Over	.34	288	.475
	Left	.36	288	.481
	Right	.39	288	.488
	Total	.36	864	.481

Report

% Hits

FIRPOS	RANGE	Mean	N	Std. Deviation
Stand	50	.77	75	.421
	100	.63	75	.487
	150	.48	75	.503
	200	.23	75	.421
	250	.15	75	.356
	300	.05	75	.226
	Total	.38	450	.487
Kneel	50	.77	69	.425
	100	.45	69	.501
	150	.36	69	.484
	200	.25	69	.434
	250	.12	69	.323
	300	.09	69	.284
	Total	.34	414	.474
Total	50	.77	144	.422
	100	.54	144	.500
	150	.42	144	.496
	200	.24	144	.426
	250	.13	144	.340
	300	.07	144	.255
	Total	.36	864	.481

Report

% Hits

EXPOSURE	RANGE	Mean	N	Std. Deviation
8	50	.50	48	.505
	100	.33	48	.476
	150	.35	48	.483
	200	.15	48	.357
	250	.04	48	.202
	300	.04	48	.202
	Total	.24	288	.425
12	50	.94	48	.245
	100	.50	48	.505
	150	.40	48	.494
	200	.21	48	.410
	250	.15	48	.357
	300	.13	48	.334
	Total	.39	288	.488
16	50	.87	48	.334
	100	.79	48	.410
	150	.52	48	.505
	200	.35	48	.483
	250	.21	48	.410
	300	.04	48	.202
	Total	.47	288	.500
Total	50	.77	144	.422
	100	.54	144	.500
	150	.42	144	.496
	200	.24	144	.426
	250	.13	144	.340
	300	.07	144	.255
	Total	.36	864	.481

Report

% Hits

FIRPOS	EXPOSURE	RANGE	Mean	N	Std. Deviation
Stand	8	50	.52	25	.510
		100	.40	25	.500
		150	.28	25	.458
		200	.08	25	.277
		250	.08	25	.277
		300	.04	25	.200
		Total	.23	150	.424
	12	50	.92	25	.277
		100	.60	25	.500
		150	.52	25	.510
		200	.28	25	.458
		250	.12	25	.332
		300	.08	25	.277
		Total	.42	150	.495
	16	50	.88	25	.332
		100	.88	25	.332
		150	.64	25	.490
		200	.32	25	.476
		250	.24	25	.436
		300	.04	25	.200
		Total	.50	150	.502
	Total	50	.77	75	.421
		100	.63	75	.487
		150	.48	75	.503
		200	.23	75	.421
		250	.15	75	.356
		300	.05	75	.226
		Total	.38	450	.487
Kneel	8	50	.48	23	.511
		100	.26	23	.449
		150	.43	23	.507
		200	.22	23	.422
		250	.00	23	.000
		300	.04	23	.209
		Total	.24	138	.428
	12	50	.96	23	.209
		100	.39	23	.499
		150	.26	23	.449
		200	.13	23	.344
		250	.17	23	.388
		300	.17	23	.388
		Total	.35	138	.478
	16	50	.87	23	.344
		100	.70	23	.470
		150	.39	23	.499
		200	.39	23	.499
		250	.17	23	.388
		300	.04	23	.209
		Total	.43	138	.497
	Total	50	.77	69	.425
		100	.45	69	.501
		150	.36	69	.484
		200	.25	69	.434
		250	.12	69	.323
		300	.09	69	.284
		Total	.34	414	.474
Total	8	50	.50	48	.505
		100	.33	48	.476
		150	.35	48	.483
		200	.15	48	.357
		250	.04	48	.202
		300	.04	48	.202
		Total	.24	288	.425
	12	50	.94	48	.245
		100	.50	48	.505
		150	.40	48	.494
		200	.21	48	.410
		250	.15	48	.357
		300	.13	48	.334
		Total	.39	288	.488
	16	50	.87	48	.334
		100	.79	48	.410
		150	.52	48	.505
		200	.35	48	.483
		250	.21	48	.410
		300	.04	48	.202
		Total	.47	288	.500
	Total	50	.77	144	.422
		100	.54	144	.500
		150	.42	144	.496
		200	.24	144	.426
		250	.13	144	.340
		300	.07	144	.255
		Total	.36	864	.481

G-3 M4 Night Firing

Means

% Hits * SIGHT

% Hits

SIGHT	Mean	N	Std. Deviation
Direct	.36	192	.481
HMD	.11	180	.315
Total	.24	372	.427

% Hits * FIREPOS

% Hits

FIREPOS	Mean	N	Std. Deviation
foxhole	.26	180	.437
standing	.22	192	.418
Total	.24	372	.427

% Hits * EXPOSURE

% Hits

EXPOSURE	Mean	N	Std. Deviation
5	.17	186	.378
8	.31	186	.462
Total	.24	372	.427

% Hits * RANGE

% Hits

RANGE	Mean	N	Std. Deviation
50	.65	62	.482
100	.35	62	.482
150	.19	62	.398
200	.13	62	.338
250	.03	62	.178
300	.08	62	.275
Total	.24	372	.427

Report

% Hits

SIGHT	FIREPOS	Mean	N	Std. Deviation
Direct	foxhole	.38	96	.487
	standing	.34	96	.477
	Total	.36	192	.481
HMD	foxhole	.12	84	.326
	standing	.10	96	.307
	Total	.11	180	.315
Total	foxhole	.26	180	.437
	standing	.22	192	.418
	Total	.24	372	.427

Report

% Hits

SIGHT	EXPOSURE	Mean	N	Std. Deviation
Direct	5	.29	96	.457
	8	.43	96	.497
	Total	.36	192	.481
HMD	5	.04	90	.207
	8	.18	90	.384
	Total	.11	180	.315
Total	5	.17	186	.378
	8	.31	186	.462
	Total	.24	372	.427

Report

% Hits

SIGHT	RANGE	Mean	N	Std. Deviation
Direct	50	.75	32	.440
	100	.59	32	.499
	150	.38	32	.492
	200	.25	32	.440
	250	.03	32	.177
	300	.16	32	.369
	Total	.36	192	.481
HMD	50	.53	30	.507
	100	.10	30	.305
	150	.00	30	.000
	200	.00	30	.000
	250	.03	30	.183
	300	.00	30	.000
	Total	.11	180	.315
Total	50	.65	62	.482
	100	.35	62	.482
	150	.19	62	.398
	200	.13	62	.338
	250	.03	62	.178
	300	.08	62	.275
	Total	.24	372	.427

Report

% Hits

FIREPOS	EXPOSURE	Mean	N	Std. Deviation
foxhole	5	.20	90	.402
	8	.31	90	.466
	Total	.26	180	.437
standing	5	.15	96	.355
	8	.30	96	.462
	Total	.22	192	.418
Total	5	.17	186	.378
	8	.31	186	.462
	Total	.24	372	.427

Report

% Hits

FIREPOS	RANGE	Mean	N	Std. Deviation
foxhole	50	.67	30	.479
	100	.33	30	.479
	150	.23	30	.430
	200	.17	30	.379
	250	.03	30	.183
	300	.10	30	.305
	Total	.26	180	.437
standing	50	.63	32	.492
	100	.37	32	.492
	150	.16	32	.369
	200	.09	32	.296
	250	.03	32	.177
	300	.06	32	.246
	Total	.22	192	.418
Total	50	.65	62	.482
	100	.35	62	.482
	150	.19	62	.398
	200	.13	62	.338
	250	.03	62	.178
	300	.08	62	.275
	Total	.24	372	.427

Report

% Hits

EXPOSURE	RANGE	Mean	N	Std. Deviation
5	50	.35	31	.486
	100	.32	31	.475
	150	.16	31	.374
	200	.13	31	.341
	250	.03	31	.180
	300	.03	31	.180
	Total	.17	186	.378
8	50	.94	31	.250
	100	.39	31	.495
	150	.23	31	.425
	200	.13	31	.341
	250	.03	31	.180
	300	.13	31	.341
	Total	.31	186	.462
Total	50	.65	62	.482
	100	.35	62	.482
	150	.19	62	.398
	200	.13	62	.338
	250	.03	62	.178
	300	.08	62	.275
	Total	.24	372	.427

Report

% Hits

EXPOSURE	RANGE	Mean	N	Std. Deviation
5	50	.32	28	.476
	100	.32	28	.476
	150	.14	28	.356
	200	.11	28	.315
	250	.04	28	.189
	300	.04	28	.189
	Total	.16	168	.368
8	50	1.00	28	.000
	100	.36	28	.488
	150	.21	28	.418
	200	.14	28	.356
	250	.04	28	.189
	300	.14	28	.356
	Total	.32	168	.466
Total	50	.66	56	.478
	100	.34	56	.478
	150	.18	56	.386
	200	.13	56	.334
	250	.04	56	.187
	300	.09	56	.288
	Total	.24	336	.427

G-4 M249 Day Firing

Means

% Hits * SIGHT

% Hits

SIGHT	Mean	N	Std. Deviation
DVS	.28	72	.451
MGO	.47	72	.503
Total	.38	144	.486

% Hits * FIREPOS

% Hits

FIREPOS	Mean	N	Std. Deviation
foxhole	.39	72	.491
prone	.36	72	.484
Total	.38	144	.486

% Hits * EXPOSURE

% Hits

EXPOSURE	Mean	N	Std. Deviation
6	.23	48	.425
8	.46	48	.504
10	.44	48	.501
Total	.38	144	.486

% Hits * RANGE

% Hits

RANGE	Mean	N	Std. Deviation
200	.69	36	.467
300	.33	36	.478
400	.33	36	.478
500	.14	36	.351
Total	.38	144	.486

Report

%Hits

SIGHT	FIREPOS	Mean	N	Std. Deviation
DVS	foxhole	.25	36	.439
	prone	.31	36	.467
	Total	.28	72	.451
MGO	foxhole	.53	36	.506
	prone	.42	36	.500
	Total	.47	72	.503
Total	foxhole	.39	72	.491
	prone	.36	72	.484
	Total	.38	144	.486

Report

% Hits

SIGHT	EXPOSURE	Mean	N	Std. Deviation
DVS	6	.17	24	.381
	8	.25	24	.442
	10	.42	24	.504
	Total	.28	72	.451
MGO	6	.29	24	.464
	8	.67	24	.482
	10	.46	24	.509
	Total	.47	72	.503
Total	6	.23	48	.425
	8	.46	48	.504
	10	.44	48	.501
	Total	.38	144	.486

Report

% Hits

SIGHT	RANGE	Mean	N	Std. Deviation
DVS	200	.50	18	.514
	300	.17	18	.383
	400	.33	18	.485
	500	.11	18	.323
	Total	.28	72	.451
MGO	200	.89	18	.323
	300	.50	18	.514
	400	.33	18	.485
	500	.17	18	.383
	Total	.47	72	.503
Total	200	.69	36	.467
	300	.33	36	.478
	400	.33	36	.478
	500	.14	36	.351
	Total	.38	144	.486

Report

% Hits

EXPOSURE	RANGE	Mean	N	Std. Deviation
6	200	.58	12	.515
	300	.25	12	.452
	400	.08	12	.289
	500	.00	12	.000
	Total	.23	48	.425
8	200	.83	12	.389
	300	.42	12	.515
	400	.42	12	.515
	500	.17	12	.389
	Total	.46	48	.504
10	200	.67	12	.492
	300	.33	12	.492
	400	.50	12	.522
	500	.25	12	.452
	Total	.44	48	.501
Total	200	.69	36	.467
	300	.33	36	.478
	400	.33	36	.478
	500	.14	36	.351
	Total	.38	144	.486

G-5 M249 Night Firing

Means

% Hits * SIGHT

% Hits

SIGHT	Mean	N	Std. Deviation
TWS Direct	.46	72	.502
TWS Through HMD	.36	72	.484
Total	.41	144	.493

% Hits * FIREPOS

% Hits

FIREPOS	Mean	N	Std. Deviation
foxhole	.35	72	.479
prone	.47	72	.503
Total	.41	144	.493

% Hits * EXPOSURE

% Hits

EXPOSURE	Mean	N	Std. Deviation
6	.21	48	.410
8	.48	48	.505
10	.54	48	.504
Total	.41	144	.493

% Hits * RANGE

% Hits

RANGE	Mean	N	Std. Deviation
200	.50	36	.507
300	.53	36	.506
400	.33	36	.478
500	.28	36	.454
Total	.41	144	.493

Report

% Hits

SIGHT	EXPOSURE	Mean	N	Std. Deviation
TWS Direct	6	.25	24	.442
	8	.54	24	.509
	10	.58	24	.504
	Total	.46	72	.502
TWS Through HMD	6	.17	24	.381
	8	.42	24	.504
	10	.50	24	.511
	Total	.36	72	.484
Total	6	.21	48	.410
	8	.48	48	.505
	10	.54	48	.504
	Total	.41	144	.493

Report

% Hits

SIGHT	RANGE	Mean	N	Std. Deviation
TWS Direct	200	.61	18	.502
	300	.56	18	.511
	400	.39	18	.502
	500	.28	18	.461
	Total	.46	72	.502
TWS Through HMD	200	.39	18	.502
	300	.50	18	.514
	400	.28	18	.461
	500	.28	18	.461
	Total	.36	72	.484
Total	200	.50	36	.507
	300	.53	36	.506
	400	.33	36	.478
	500	.28	36	.454
	Total	.41	144	.493

Appendix H. Raw Weapon Compatibility Data

Grenadier – M4-M203   TP # 3   Stature 178.0 cm – 64th percentile

FLC

IRON

Standing – ok

Kneeling – ok

Prone - ok

CCO

Standing – ok

Kneeling – ok

Prone – ok

TWS

Standing – ok

Kneeling – ok

Prone – ok

DVS

Standing – ok

Kneeling – ok

Prone - ok

Grenadier – M4-M203 TP #3 **Stature 178.0 cm – 64th percentile**

<u>FLC with BALCS</u>

IRON

Standing – OK – Better than in kneeling position, not as restrictive.

Kneeling – Restrictive in shoulders

Prone – Not a good sight picture. Neck on BALCS pushes helmet down which pushes glasses down.

CCO

Standing – Not as restrictive in shoulders as kneeling position.

Kneeling – Restricive in shoulders. Not good buttstock position.

Prone – Pushes helmet down. Restricts vision. Can get sight picture for low targets.

TWS

Standing – Eyecup difficult to get correct. Not LW specific. Buttstock not seated properly.

Kneeling – Eyecup difficult to get correct. Not LW specific. Buttstock not seated properly.

Prone – With specs on, hard to open eyecup on TWS. Eyecup hits helmet. This is difficult even bareheaded.

DVS

Standing – Restricive in shoulders

Kneeling – Restrictive in shoulders

Prone – Head pushed down. Helmet restricts vision.

Grenadier – M4-M203 TP #3 Stature 178.0 cm – 64^{th} percentile

FLC with BALCS and Assault Pack

IRON

Standing – Buttstock position on shoulder is not good. Weapon slips down to bicep. All the straps make shoulder movement restricted.

Kneeling – Buttstock position on shoulder is not good. Weapon slips down to bicep. All the straps make shoulder movement restricted.

Prone – Helmet pushing down and restricts vision. Can't aim at high targets. Difficult to use pad.

CCO

Standing – Helmet pushed down slightly

Kneeling – Helmet pushed down. Buttstock on arm. Restrictive in shoulders.

Prone – Helmet pushing down. VERY difficult to get sight picture.

TWS

Standing – Can get sight picture but it is difficult.

Kneeling – Can't even get good sight picture – very difficult.

Prone – No sight picture. Pack pushes head down. Head at angle and won't push eye cup open properly.

DVS

* All same as iron sights

Grenadier – M4-M203 TP #3 Stature 178.0 cm – 64^{th} percentile

FLC with assault pack

IRON

Standing – Not a good shoulder hold with buttstock. Strap from assault pack interferes.

Kneeling – Not a good shoulder hold with buttstock.

Prone – Helmet pushes down a little on glasses. Can still see target. In proper firing position.

CCO

Standing – Shoulder hold not good. Assault pack strap interferes.

Kneeling – Shoulder hold not good. Assault pack strap interferes.

Prone – Plastic piece on assault pack hit helmet. Still good firing position.

TWS

Standing – Eyecup is easier to use than when in prone position.

Kneeling – Eyecup is easier to use than when in prone position.

Prone – Hard to open eyecup on TWS. Eyecup hits helmet, hard even when bareheaded. Not a land warrior specific problem.

DVS

Standing – Buttons difficult to press, very difficult to zoom.

Kneeling – Buttons difficult to press, very difficult to zoom.

Prone - Buttons difficult to press, very difficult to zoom.

** Good access to 203. No problem firing it. DVS in the way a little bit for loading 203 round.

Rifleman – M4 TP #4 Stature 190.3 cm – 99th percentile

FLC

IRON

Standing – ok

Kneeling – ok

Prone - ok

CCO

Standing – ok

Kneeling – ok

Prone – ok

TWS

Standing – To open eyecup properly, have to move buttstock of weapon up on shoulder.

Kneeling – To open eyecup properly, have to move buttstock of weapon up on shoulder.

Prone – ok

DVS

Standing – ok

Kneeling – ok

Prone - ok

Rifleman – M4   TP #4   Stature 190.3 cm – 99th percentile

FLC with BALCS

IRON

Standing – ok

Kneeling – Buttstock position not good

Prone – Can shoot but head is forced down. Have to cock head to right.

CCO

Standing –

Kneeling – Buttstock position not good

Prone – Can shoot but head movement is restricted.

TWS

Standing – Buttstock position is not good, eyecup causing problems.

Kneeling – Eyecup is difficult to use.

Prone – NO GO. Head is forced down, can't open eyecup properly to fire.

DVS

Standing – ok.

Kneeling – Buttstock position is not good.

Prone – Can shoot but head forced down.

Rifleman – M4 TP #4 Stature 190.3 cm – 99th percentile

<u>FLC with BALCS and Assault Pack</u>

IRON

Standing – Buttstock on bicep.

Kneeling – Buttstock on bicep.

Prone – NO GO. Head pushed forward. Can only see 6 ft in front.

CCO

Standing – Buttstock on bicep.

Kneeling – Buttstock on bicep.

Prone – NO GO. Can't fire.

TWS

Standing – Eyecup is problem. Buttstock not in correct position.

Kneeling – Eyecup is problem. Buttstock on top of shoulder.

Prone – NO GO. Because head is pushed down can't open eyecup properly.

DVS

Standing – ok.

Kneeling – ok.

Prone – Can only see 6 feet in front without DVS. To use DVS would have to acquire target using it. DVS is probably only way to fire in this configuration.

Rifleman – M4 TP #4 Stature 190.3 cm – 99th percentile

FLC with assault pack

IRON

Standing – ok. Good access to controls.

Kneeling – ok.

Prone - ok.

CCO

Standing – ok.

Kneeling – ok.

Prone – ok. Cable is long enough, even for his tall stature. Sometimes cable loops up and gets in his face.

TWS

Standing – Eyecup requires several tries to open correctly.

Kneeling – Eyecup requires several tries to open correctly.

Prone – Not full picture. Eyecup obscures part of FOV. Not better without specs.

DVS

Standing – ok. Buttstock ok

Kneeling – ok. Buttstock ok.

Prone – ok.

Grenadier – M4-M203 TP#8 Stature 172.0 cm – 30th percentile

* sling may interfere with manipulating selector switch

FLC

IRON

Standing – Zoom wheel not conveniently located. #2920

Kneeling – ok.

Prone – Hard to access zoom knob.

CCO

Standing – ok.

Kneeling – ok.

Prone – Hard to access zoom knob.

TWS

Standing – Trouble with eyecup.

Kneeling – Zoom knob and pad on weapon tough to reach. Can't see them with TWS mounted.

Prone – Eyecup difficult to use

DVS

Standing – ok.

Kneeling – ok.

Prone – Sling goes in front of DVS. #2922

Grenadier – M4-M203 TP#8 Stature 172.0 cm – 30^{th} percentile

FLC with BALCS

IRON

Standing – Trying to jam arm in side for support, 203 rounds jab in arm. Zoom knob.

Kneeling – Buttstock slipping to arm.

Prone – Access to zoom is difficult. Helmet is pushing forward. Buttstock not seated properly – on arm. #2925

CCO

Standing – see iron

Kneeling – see iron

Prone – see iron

TWS

Standing – Needed to use hand to get eyecup correct. Problem even without specs.

Kneeling – Buttstock and eyecup issues.

Prone – Buttstock not seated properly. Helmet pushing forward and blocking view. Can get sight picture if eyecup is manipulated with hand.

DVS

Standing – Same as iron, sling in way.

Kneeling – see iron.

Prone – Hard to look at HMD. When getting in prone firing position helmet shifts and HMD moves from set position.

Grenadier – M4-M203 TP#8 **Stature 172.0 cm – 30th percentile**

<u>FLC with BALCS and Assault Pack</u>

IRON

Standing – Buttstock not seating in shoulder properly.

Kneeling – Buttstock not seating in shoulder properly. #2929

Prone – NO GO. Assault pack pushing helmet. Can't see target without pushing up helmet with other hand. Can't line up sights with target.

CCO

Standing – see iron

Kneeling – see iron

Prone – see iron

TWS

Standing – Had to manipulate eyecup with hand. Buttstock way on shoulder to open eyecup properly. #2931

Kneeling – see standing

Prone – NO GO. Can't see target – even without sight.

DVS

Standing – same as iron – sling can get in way. Good access to buttons except for zoom.

Kneeling – same as iron access to zoom is difficult.

Prone – Can't see target with eyes but could search with DVS and fire. Since helmet is pushed forward, need to reposition HMD.

Grenadier – M4-M203 TP#8 Stature 172.0 cm – 30th percentile

FLC with assault pack

IRON

Standing – Some buttstock issues but better than when wearing body armour.

Kneeling – same as standing

Prone – Helmet still pushing forward but can see target. Buttstock will not tuck in properly.

CCO

Standing – same as iron.

Kneeling – same as iron.

Prone – same as iron.

TWS

Standing – Had to use hand to get eyecup correct. Buttstock up on shoulder to open eyecup.

Kneeling – Same as standing.

Prone – Need to use hand to push open eyecup. Can see target, helmet pushed forward but using eyecup to keep helmet up.

DVS

Standing – Difficult to reach zoom knob

Kneeling – see iron.

Prone – see iron.

SAW Gunner TP#10 Stature 178.7 cm – 68th percentile

FLC

IRON

Prone – TWS cable in way, can't get sight picture. #2927

Can reach buttons on port handle but have to remove. #2921

MGO

Prone – ok.

TWS

Prone – Neck unsupported due to high position of the TWS. #2924
Eyecup has to be collapsed just right to get it to work.

DVS

Prone – Need to switch hands between buttstock support and UID. Soldier would not be able to fully control weapon when zooming in and out.

SAW Gunner TP#10 **Stature 178.7 cm – 68th percentile**

<u>FLC with BALCS</u>

IRON

Prone – SAW shoulder support wire (buttstock) slides off shoulder. Can't get support on shoulder (#2928). Hard to lift neck to search target area. Also right and left head turning hard.

MGO

Prone – Due to height of MGO and interference of XXXX, hard to raise head to get good sight picture. Can reach charging handle but with slight difficulty.

TWS

Prone – Had to turn head almost sideways to get into eyecup (#2930), would not be able to hold position to maintain fire. TWS too high and eyecup too high, more neck strain than without BALCS.

DVS

Prone – ok.

SAW Gunner TP#10 Stature 178.7 cm – 68th percentile

FLC with BALCS and Assault Pack

IRON

Prone – NO GO. Can't get sight picture due to rear of helmet hitting off assault pack. # 2932.

MGO

Prone – NO GO. Same as standing. #2935. #2936

TWS

Prone – NO GO. Can't get right eye in eyecup due to intereference between assault pack and helmet. #2939. #2940

DVS

Prone – ok. Would have to acquire targets through DVS.

SAW Gunner TP#10 Stature 178.7 cm – 68th percentile

<u>FLC with assault pack</u>

IRON

Prone – Cable interference with sight picture.

MGO

Prone – ok.

TWS

Prone – ok. TWS just a little high.

DVS

Prone -

Rifleman – M4 TP #11 Stature 171.3 cm – 27th percentile

FLC

IRON

Standing – ok

Kneeling – ok

Prone - ok

Right safety interferes when engaging with right hand

CCO

Standing – ok

Kneeling – ok

Prone – ok

TWS

High eye cup

Standing – ok

Kneeling – ok

Prone – ok

DVS

Standing – ok

Kneeling – ok

Prone - ok

Rifleman – M4 TP #11 Stature 171.3 cm – 27th percentile

FLC with BALCS

IRON

Standing – Buttstock slides off shoulder, can't get good stock weld. Collar interferes when trying to get good stock weld.

Kneeling – Has to raise arm higher to get better stock weld

Prone – Helmet strap interferes with collar. Body armour feels too wide. Can'r get comfortable grip on front of weapon.

CCO

Standing – see iron

Kneeling – see iron

Prone – see iron.

TWS

Standing – No buttstock in shoulder.

Kneeling – No stock weld, no buttstock in shoulder pocket.

Prone – NO GO. Can't use eyecup in prone. Helmet and spectacles interference. Hard to raise head due to collar.

DVS

Standing – see iron

Kneeling – see iron.

Prone – see iron

Rifleman – M4 TP #11 Stature 171.3 cm – 27^{th} percentile

<u>FLC with BALCS and Assault Pack</u>

IRON

Standing – Buttstock not seated properly in shoulder (#2943).

Kneeling – Buttstock not seated properly in shoulder.

Prone – NO GO. No way to fire.

CCO

Standing – same as iron

Kneeling – same as iron

Prone – same as iron

TWS

Standing – Difficult to get eyecup open. Not flexible and all the stuff on shoulder.

Kneeling – Eyecup is problem, had to work to get it open correctly. Buttstock on top of shoulder.

Prone – NO GO. Assault pack pushing helmet forward. Can't begin to lift up weapon. Can't see target in normal firing position.

DVS

Standing – same as iron

Kneeling – same as iron

Prone – Wouldn't be able to use without DVS in prone. To use DVS would have to acquire target using it. DVS is probably only way to fire in this configuration and firing position.

Rifleman – M4 TP #11 Stature 171.3 cm – 27th percentile

FLC with assault pack

IRON

Standing – Buttstock a little tough to seat. Better than when had body armour.

Kneeling – Buttstock a little tough to seat. Better than when had body armour.

Prone – Helmet pushed down a little and blocks some view of target area Able to push up helmet and sight in on target.

CCO

Standing – see iron

Kneeling – see iron

Prone – see iron

TWS

Standing – Buttstock pocket not great.

Kneeling – Eyecup requires several tries to open correctly. Buttstock not seated well on shoulder

Prone – Can't get eyecup working very easily. Helmet pushed down on eyecup. Very difficult.

DVS

Standing – see iron

Kneeling – see iron

Prone – Can use with DVS. Have to reset position of HMD because when you get in pron helmet pushes forward and HMD becomes non-visible until reset.

SAW Gunner TP#6 Stature 171.3 cm – 27th percentile

FLC

IRON

Prone – Cable retainer clips for TWS in way, right in visual path. Would have to remove them to fire through iron sights.

MGO

Prone – ok.

TWS

Prone – Hard to get eyecup opened properly. To reach controls have to reach forward – not the normal firing position.

SAW Gunner TP#6 Stature 171.3 cm – 27th percentile

FLC with BALCS

IRON

Prone – Could fire but hard. Could extend legs to help but would not be able to traverse easily

MGO

Prone - Head was pushed down but could fire.

TWS

Prone – NO GO – can't fire, head pushed down and eyecup is a problem..

SAW Gunner TP#6 Stature 171.3 cm – 27th percentile

FLC with BALCS and Assault Pack

IRON

Prone – Can get sight picture but hard. Can get at high targets only if extend legs of bipod.

MGO

Prone – NO GO - Buttstock slides off shoulder. Can't get sight picture. Head is pushed down too far.

TWS

Prone – NO GO. Can't push eyecup in to see sight picture.

SAW Gunner TP#6 Stature 171.3 cm – 27th percentile

<u>FLC with assault pack</u>

IRON

Prone –

MGO

Prone –

TWS

Prone –

DVS

Prone -

Appendix I. Obstacle Course Completion Time Data

Means

TIME * TRIAL

TIME

TRIAL	Mean	N	Std. Deviation
BDU	245.6867	12	34.62942
LW	444.5858	12	111.65621
LW BALCS + PLATES	559.8092	12	105.62938
Total	416.6939	36	158.48421

TIME * CONFIG

TIME

CONFIG	Mean	N	Std. Deviation
rifleman	366.0525	12	115.64758
grenadier	409.6358	12	142.82755
saw gunner	474.3933	12	199.14948
Total	416.6939	36	158.48421

Report

TIME

TRIAL	CONFIG	Mean	N	Std. Deviation
BDU	rifleman	244.4750	4	51.82727
	grenadier	248.2475	4	25.48257
	saw gunner	244.3375	4	32.38053
	Total	245.6867	12	34.62942
LW	rifleman	363.5450	4	53.50998
	grenadier	436.4575	4	90.74305
	saw gunner	533.7550	4	123.16119
	Total	444.5858	12	111.65621
LW BALCS + PLATES	rifleman	490.1375	4	56.95610
	grenadier	544.2025	4	77.99714
	saw gunner	645.0875	4	122.84157
	Total	559.8092	12	105.62938
Total	rifleman	366.0525	12	115.64758
	grenadier	409.6358	12	142.82755
	saw gunner	474.3933	12	199.14948
	Total	416.6939	36	158.48421

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Appendix J. Equipment Configuration Descriptions

LW "Rifleman" LBE

The LW "Rifleman" LBE is shown in figure J-1. The LBE has padded shoulder straps, and several ammunition and grenade pouches are situated along its front. A general purpose pouch is also situated on the right side of the LBE. Several straps and buckles on the LBE allow for proper adjustment.

Figure J-1. LW "rifleman" LBE.

BALCS

BALCS consists of body armor, an equipment load-carrying subsystem, and a backpack subsystem; however, in this study, only the body armor component was used (see figure J-2). The body armor component provides ballistic protection and consists of a soft armor vest, front and back interchangeable upgrade plates, and modular neck and groin protection. The vest is available in four sizes ranging from small to extra large, and the plates are sized with the vest. A medium sized vest weighs approximately 6.5 lb, and the corresponding plates weighs approximate 6 lb each.

JSLIST

The JSLIST is a two-piece garment (hooded coat and trousers), featuring state-of-the-art chemical protective lining technology, which provides increased chemical protection while allowing more mobility for the Soldier. It is compatible with individual weapons, protective

masks, footwear, and standard chemical individual equipment at all mission-oriented protective posture levels. In this study, both parts of the garment were worn, as well as a protective mask with canister, but the protective gloves and boots were not worn in this study (see figure J-3).

Figure J-2. BALCS body armor.

Figure J-3. JSLIST.

Appendix K. Procedures for Joint Motion Measurement

Head Flexion

The subject begins in standing position with his head and neck in anatomic position (see figure K-1a). The head is then tilted anteriorly in the sagittal plane until the end of ROM is reached (see figure K-1b). The goniometer is aligned so that the fulcrum is placed close to base of neck, the stationary arm is aligned with the mid-axillary line of the trunk and the moving arm is aligned with the mastoid process (see figure K-1b). The average ROM for head flexion is 0° to 45°.

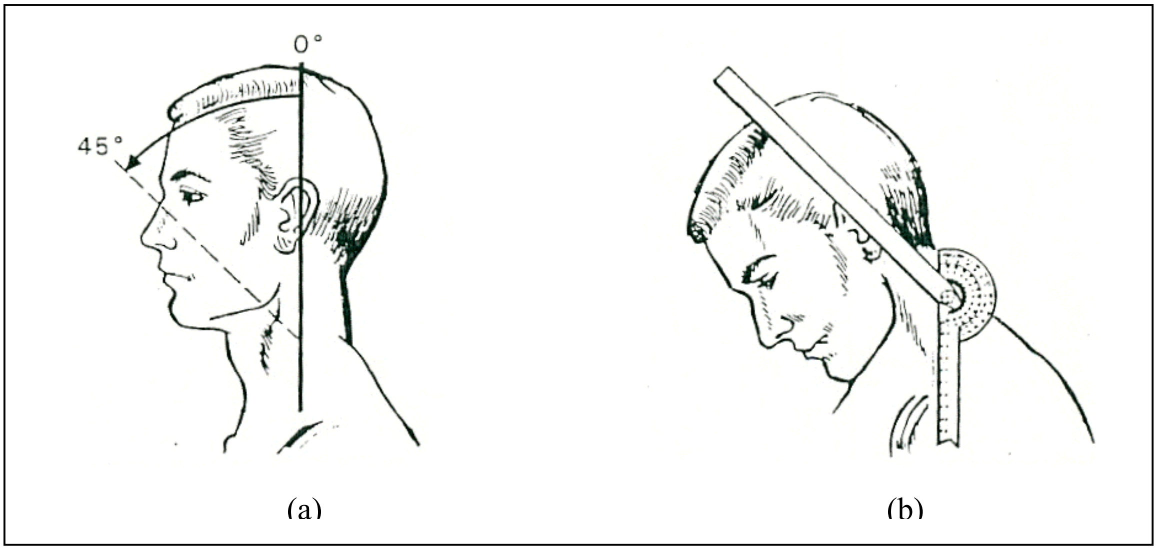


Figure K-1. Head flexion.

Head Extension

The subject begins in standing position with his head and neck in anatomic position (see figure K-2a). The head is then tilted posteriorly in the sagittal plane until the end of ROM is reached (see figure K-2b). The goniometer is aligned so that the fulcrum is placed close to base of neck, the stationary arm is aligned with the mid-axillary line of the trunk and the moving arm is aligned with the mastoid process (see figure K-2b). The average ROM for head extension is 0° to 45°.

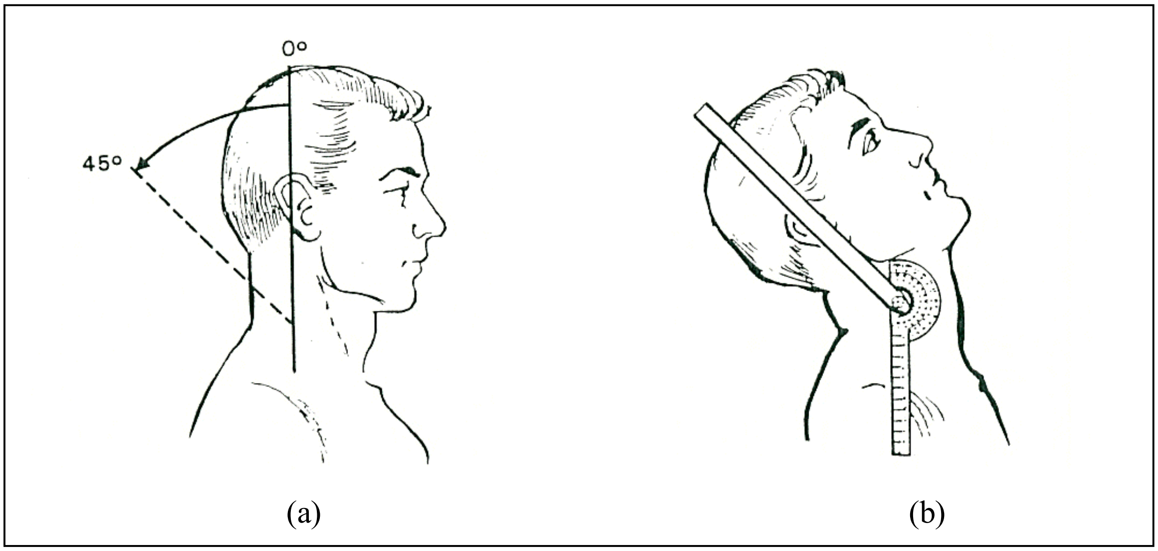


Figure K-2. Head extension.

Head Rotation

The subject begins in a standing position with his head and neck in anatomic position. The head is then rotated laterally (left or right) about the longitudinal axis in the transverse plane until the end of ROM is reached (see figure K-3). The goniometer is placed on top of the head and aligned so that the fulcrum is over the midpoint of an imaginary line connecting the ears, the stationary arm is aligned with the jugular notch, and the moving arm is aligned with the nose. The average ROM for head rotation is 0° to 60°.

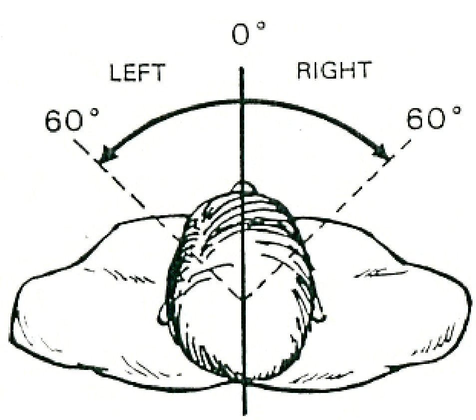
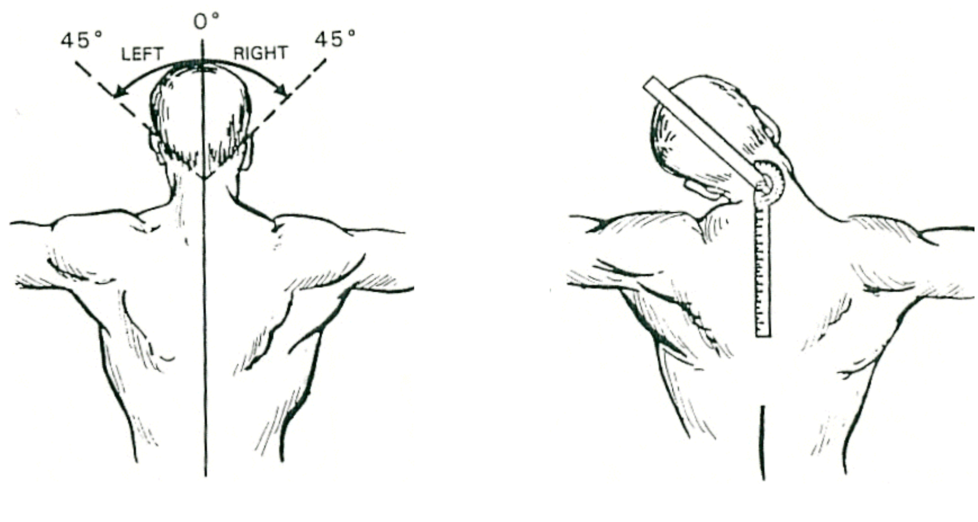


Figure K-3. Head rotation.

Head Lateral Bending

The subject begins in a standing position with his head and neck in anatomic position (see figure K-4a). The head is then tilted laterally (left or right) in the frontal plane until the end of ROM is reached (see figure K-4b). The goniometer is placed against the back of the neck and aligned so that the fulcrum is at the level of the spinous process of vertebrae C4 or C5, the stationary arm is aligned parallel to the midline of the trunk and the moving arm is aligned with the occipital protuberance (see figure K-4b). The average ROM for head lateral bending is 0° to 45°.



(a) (b)

Figure K-4. Head lateral bending.

Upper Extremity Motions

Shoulder Flexion

The subject begins in a standing position with the right arm straight at his side and palm facing in towards his body (see figure K-5a). The right arm is then raised anteriorly about the coronal axis in the sagittal plane until the end of ROM is reached (see figure K-5b). The goniometer is aligned so that the fulcrum is placed close to the acromion process, the stationary arm is aligned with the mid-axillary line of the trunk, and the moving arm is aligned with the lateral midline of the humerus (see figure K-5b). The average ROM for shoulder flexion is 0° to 180°.

Shoulder Extension

The subject begins in a standing position with the right arm straight at his side and palm facing in toward his body (see figure K-6a). The right arm is then raised posteriorly about the coronal axis in the sagittal plane until the end of ROM is reached (see figure K-6b). The goniometer is aligned so that the fulcrum is placed close to acromion process, the stationary arm is aligned with

the mid-axillary line of the trunk, and the moving arm is aligned with the lateral midline of the humerus (see figure K-6b). The average ROM for shoulder extension is 0° to 60°.

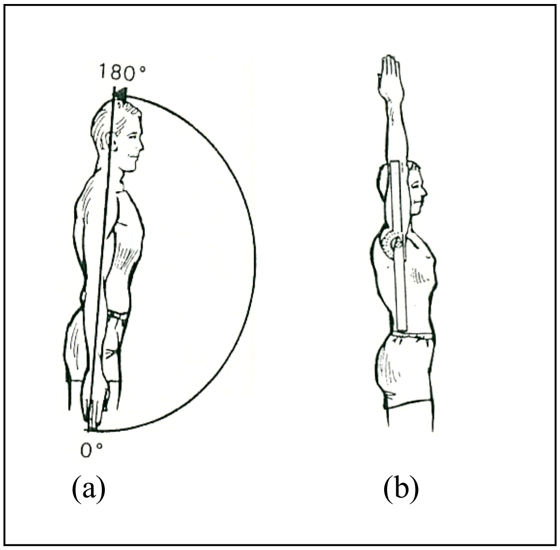


Figure K-5. Shoulder flexion.

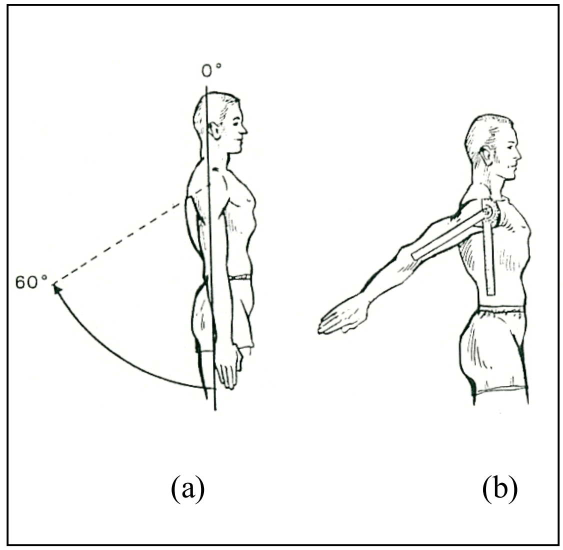


Figure K-6. Shoulder extension.

Shoulder Abduction

The subject begins in a standing position with the right arm straight at his side and palm facing in toward his body (see figure K-7a). The right arm is then raised laterally about the anterior-posterior axis in the frontal plane until the end of ROM is reached (see figure K-7b). The goniometer is aligned so that the fulcrum is placed close to the posterior aspect of the acromion process, the stationary arm is aligned with the vertebral column, and the moving arm is aligned with the lateral midline of the humerus (see figure K-7b). The average ROM for shoulder abduction is 0° to 180°.

Shoulder Adduction

The subject begins in a standing position with the right arm straight at his side and palm facing in toward his body (see figure K-8a). The right arm is then raised medially about the anterior-posterior axis in the frontal plane until the end of ROM is reached (see figure K-8b). The goniometer is aligned so that the fulcrum is placed close to the anterior aspect of the acromion process, the stationary arm is aligned with the sternum, and the moving arm is aligned with the lateral midline of the humerus (see figure K-8b). The average ROM for shoulder adduction is 0° to 75°.

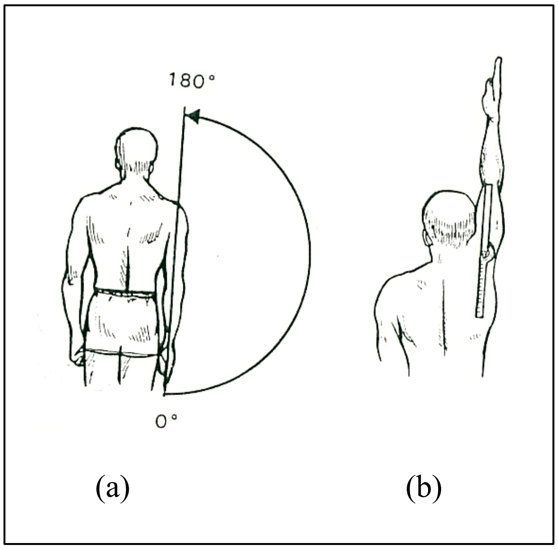


Figure K-7. Should and upper arm abduction.

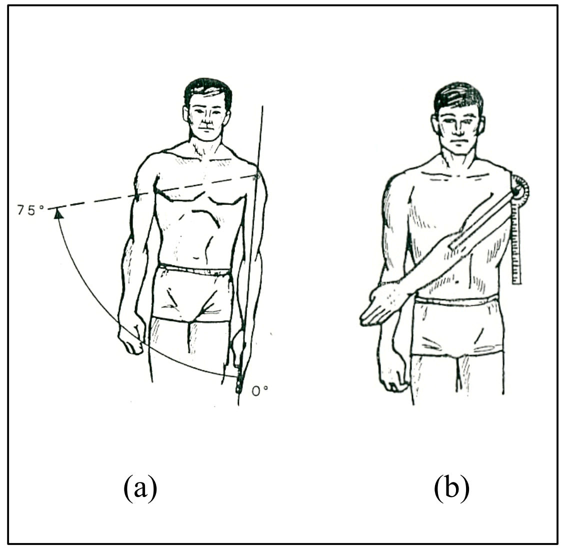


Figure K-8. Shoulder adduction.

Upper Arm Abduction

The subject begins in a standing position with both arms straight at his sides and palms facing in toward his body (see figure K-7a). Both arms are then raised laterally about the anterior-posterior axis in the frontal plane until the end of ROM is reached (see figure K-7b). The goniometer is aligned so that the fulcrum is placed close to the posterior aspect of the right acromion process, the stationary arm is aligned with the vertebral column, and the moving arm is aligned with the lateral midline of the right humerus (see figure K-7b).

Lower Extremity Motions

Hip Flexion

The subject begins in a standing position with his right hip in 0° of abduction, adduction and rotation (see figure K-9a). With flexed knee, the right leg is then raised anteriorly in the sagittal plane about the transverse axis until the end of ROM is reached (see figure K-9b). The goniometer is aligned so that the fulcrum is placed over the lateral aspect of the hip joint (greater trochanter of the femur used as a reference), the stationary arm is aligned parallel to the long axis of the trunk, and the moving arm is aligned with the lateral midline of the right femur (see figure K-9b). The average ROM for hip flexion is 0° to 120°.

Hip Extension

The subject begins in a standing position with his right hip in 0° of abduction, adduction and rotation (see figure K-10a). With a straight knee, the right leg is then raised posteriorly in the sagittal plane about the transverse axis until the end of ROM is reached (see figure K-10b). The goniometer is aligned so that the fulcrum is placed over the lateral aspect of the hip joint (greater trochanter of the femur used as a reference), the stationary arm is aligned parallel to the long axis

of the trunk, and the moving arm is aligned with the lateral midline of the right femur (see figure K-10b). The average ROM for hip extension is 0° to 30°.

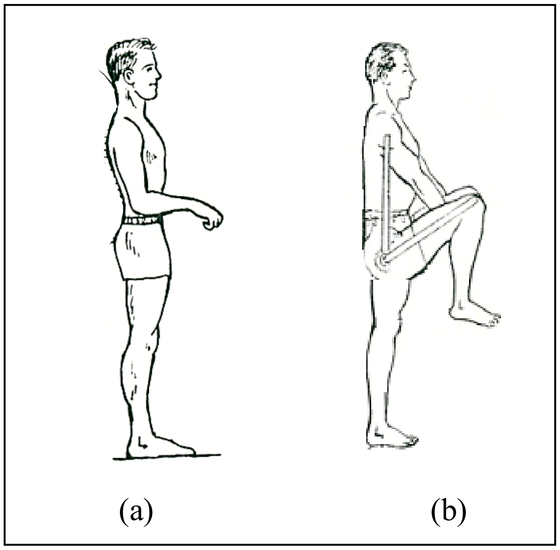


Figure K-9. Hip flexion.

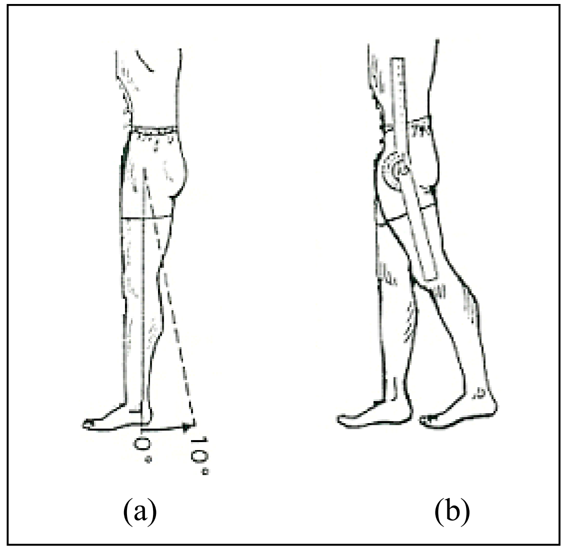


Figure K-10. Hip extension.

Standing Trunk Flexion

The subject begins in a standing position with his trunk, head, and lower extremities in their anatomic positions (see figure K-11a). With a straight back, the trunk is then tilted anteriorly in the sagittal plane about the transverse axis until the end of ROM is reached (see figure K-11b). The goniometer is aligned so that the fulcrum is placed slightly above the ilium, the stationary arm is aligned perpendicular to the floor, and the moving arm is aligned parallel to the back (see figure K-11b). The average ROM for standing trunk flexion is 0° to 80°.

Standing Trunk Extension

The subject begins in a standing position with his trunk, head, and lower extremities in their anatomic positions (see figure K-12a). With a straight back, the trunk is then tilted posteriorly in the sagittal plane about the transverse axis until the end of ROM is reached (see figure K-12b). The goniometer is aligned so that the fulcrum is placed slightly above the ilium, the stationary arm is aligned perpendicular to the floor, and the moving arm is aligned parallel to the back (see figure K-12b). The average ROM for standing trunk extension is 0° to 25°.

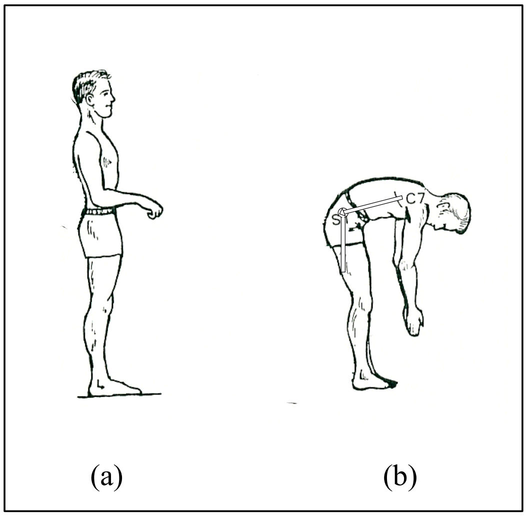


Figure K-11. Standing trunk flexion.

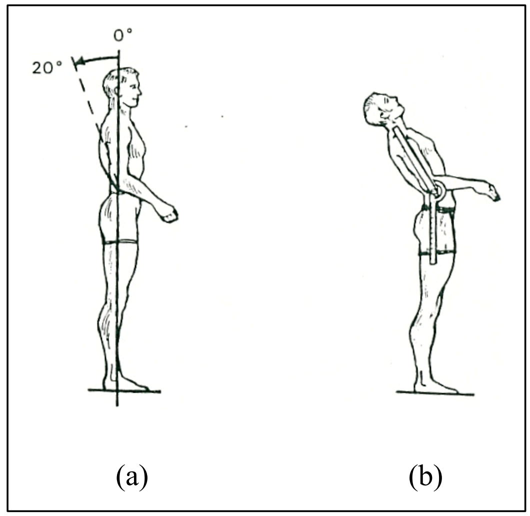


Figure K-12. Standing trunk extension.

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